DOCUMENT RESUME

ED 289 724 SE 048 809

AUTHOR Farmer, Mike
TITLE Science Projects--A Modular Approach. Third Edition.
PUB DATE Sep 87
NOTE 66p.; Pages contain small, broken type.
AVAILABLE FROM Applied Educational Technology, P.O. Box 193, Tigerville, SC 29688 ($7.50 each, $5.00 each in lots of 20).
PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052) -- Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Computer Assisted Instruction; Courseware; Data Analysis; *Elementary School Science; Elementary Secondary Education; Exhibits; *Science Activities; Science Education; Science Experiments; Science Fairs; Science Instruction; *Science Projects; *Scientific Research; *Secondary School Science; *Student Research

ABSTRACT

This document was designed to be used as a tool to assist students with research-oriented science projects. It provides a step-by-step approach to the development of such projects addressing: (1) selecting a research topic; (2) learning about the subject; (3) developing a specific purpose for the research; (4) planning the project; (5) initiating experiments; (6) analyzing data; (7) writing the final paper; (8) preparing an exhibit; and (9) entering a science competition. It includes a checklist focusing on the major steps in science research. The appendices contain some science project ideas, examples of project categories, a list of computer software that may be appropriate for certain student projects, and some criteria for judging science projects. (TW)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED289724

SCIENCE PROJECTS —→→→ A MODULAR APPROACH

by MIKE FARMER

©1986

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

X This document has been reproduced as received from the person or organization originating it.

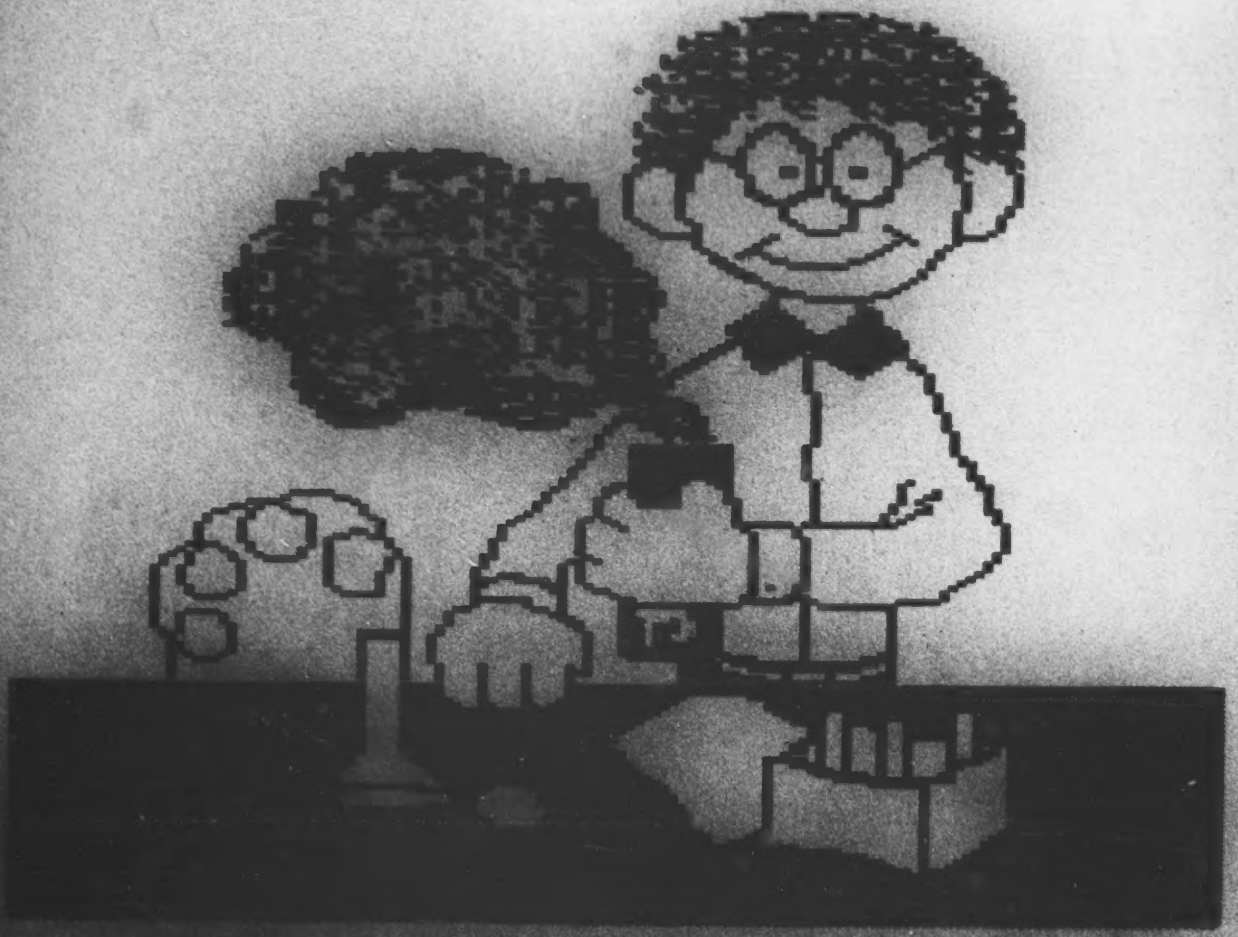
☐ Minor changes have been made to improve reproduction quality

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Michael H. Farmer

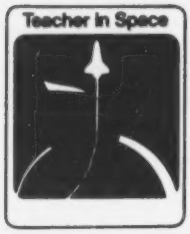
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."



SCIENCE PROJECTS
A
MODULAR
APPROACH

"It is not in the nature of things for any one man to make a sudden, violent discovery; science goes step by step, and every man depends on the work of his predecessors."

SIR ERNEST RUTHERFORD
1871-1937



COPYRIGHT 1986 MIKE FARMER
SECOND EDITION

All rights reserved. No part of this book may be reproduced in any form or by any means without written permission from the author.

Mike Farmer
Route 1,Box 315
Travelers Rest, S.C. 29690

Additional Copies of this manual available from:
Applied Educational Technology
Post Office Box 193
Tigerville, SC 29688
$7.50 each;
$5.00 each lots of 20.

THIRD EDITION - SEPTEMBER 1987

For Kenley,
who comes of age
with the Millennium.
Through wisdom and the application
of the scientific method, may we leave
your generation a world better than we found it.

PREFACE

Science Projects - A Modular Approach combats the problems of poor planning, a shortage of time, the lack of student incentives, and adequate or effective teacher direction which often plague science projects.

This modular guide is a step-by-step manual with concise instruction in the development of successful science projects - from selection of topics to exhibition techniques. Emphasizing careful planning, consistency and concern for the scientific method, the module first introduces nine steps essential to the production process and then describes and illustrates them in detail. Periodic teacher evaluation is encouraged through the use of checklists and correlated worksheets.

This edition was sponsored by an Educational Improvement Act grant from the South Carolina State Department of Education and a grant from The Alliance for Quality Education of Greenville County.

A C K N O W L E D G E M E N T S

I am deeply indebted to the following persons without whose assistance I would not have been able to write this book: above all, Kay, my wife, who spent hours proofing the text and designing the cover; Dr. Dewitt Stone, President, South Carolina Academy of Science; Dr. Gil Fairbanks, Biology Deparment, Furman University; Dr. Dan Cover, Sociology Department, Furman University; Mr Willie Whittaker, Science Consultant, School District of Greenville County; Mrs Francis Crawford, President Elect, South Carolina Science Council; Mrs Betty Hadden, President, Greenville County Science Teachers Association; Mrs Doris Clanton, Director of Instructional Services, School District of Greenville County; my students, and the science teachers of Greenville County.

I would also like to thank Govenor Richard Riley, the South Carolina Department of Education, and The Alliance for Quality Education in Greenville County for making this publication possible.

C O N T E N T S

PAGE

Introduction ---------- 1

CHECK LIST - Major Steps In Science Research -------- 2

RESEARCH STEPS

STEP ONE - Select Your Topic. ---------- 3

STEP TWO - Know Your Subject. ---------- 6

STEP THREE - Have A Purpose. ---------- 8

STEP FOUR - Plan Your Project. ---------- 10

STEP FIVE - Start Experiments. ---------- 14

STEP SIX - Analyze Data. ---------- 18

STEP SEVEN - Write Final Paper. ---------- 24

STEP EIGHT - Prepare An Exhibit. ---------- 28

STEP NINE - Enter Science Competition. ---------- 33

APPENDICES

APPENDIX A - Science Project Ideas ---------- 37

APPENDIX B - Vetebrate Animal Certification --------- 40

APPENDIX C - Computer Software ---------- 41

APPENDIX D - Appleworks Statistics Spreadsheet ------ 42

APPENDIX E - Science Fair Regulations ---------- 43

APPENDIX F - Western Carolina Science Fair ---------- 46

APPENDIX G - Aids For Your Fair ---------- 47

APPENDIX H - ISEF Project Categories ---------- 48

APPENDIX I - Judging Criteria ---------- 49

APPENDIX J - Awards At The ISEF ---------- 50

INTRODUCTION

At one time it was generally believed that vapors of onions and garlic destroyed magnetic properties of iron. Why didn't anyone have the presence of mind to rub a garlic clove over a magnet to determine if indeed the theory were true?

Such blind acceptance of a silly theory as gospel is not compatible with the disposition of Donna Cohen, recently of the third grade at Campus School, Glassboro, N.J. She wondered if food goes down into one's stomach by gravity, simply by falling down, much as an apple falls from a tree. A ready answer seems not to have been available and Donna set out to investigate the matter and form her own conclusions.

With the help of her classmates and the approval of her teacher, Donna conducted an experiment. She arranged for three girls and seven boys, each with a pillow to cushion his cranium, to stand on his head, eat a banana, and sip water through a straw. All succeeded, and Donna therefore concluded that muscles, not gravity, push food into our stomachs.

Donna entered the results of her experiment in a science fair and won a prize. Of her project she said, " In trying to make a good science project, I stated the problem clearly, figured out a way to test it, reported the findings, and drew my conclusions." This should be your approach as you begin your project.

It would be hard to imagine a more exciting time than now to be choosing a career. The greatest discoveries and the most creative dreams of this age of science are still to be realized - and you can be a part of this great adventure.

There is still time to prepare yourself to make the most of your abilities. There is time, too, to discover that the world of scientific research has many avenues leading to it and a multitude of options to choose from once you get there.

In the "Science Projects Handbook", by Shirley Moore, there are listed three exceedingly important and basic experiences that will take you a long way up the road towards becoming a scientist.

PLAN AHEAD

These vital experiences include:

(1) "- See and experience for yourself, by one means or another, what a challenging adventure the pursuit of scientific truth can be."

(2) " – discover the thrill and incomparable satisfaction of finding and proving a bit of truth for yourself."

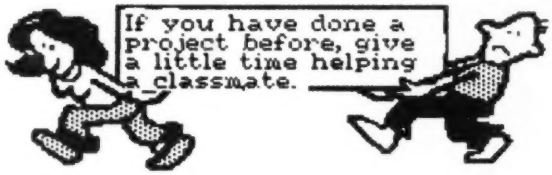
(3) " – believe that you can go on successfully searching and finding."

One of the best methods for having these experiences is to complete a science project.

SCIENCE FAIRS

A science fair provides you with an opportunity to report the results of your own particular interest. Although a fair is an exhibition, this is not its most important purpose. At the heart of a fair is the work of each student and the results of his or her experiments. Before a science fair takes place, each student must do much as Donna did above. Donna followed the 9 steps listed below in completing her science project.

1. Select your topic.
2. Know your subject.
3. Have a purpose.
4. Plan your project.
5. Start experimenting.
6. Analyze data.
7. Write final report.
8. Prepare exhibit.
9. Enter science competitions.



********ASSIGNMENT********

As you proceed through this handbook, you will be ask to do some simple exercises to help you through each of the above steps. The check list on Page 2 will help. Write the date each item is due in the blanks provided and check them off as you proceed. ASK YOUR TEACHER FOR DATES

MAJOR STEPS IN SCIENCE RESEARCH

CHECK LIST

(Check off when finished) (Due Date)

_____ I. SELECT YOUR TOPIC. _____

[ ] 1. Developed the questions to guide your research.
[ ] 2. Conducted research in library.
[ ] 3. Used "Cause and Effect" to design project.

_____ II. KNOW YOUR TOPIC. _____

[ ] 1. Searched the literature.
[ ] 2. Read and made notes in your notebook.
[ ] 3. Made a preliminary outline.
[ ] 4. Dated and recorded all notes in a notebook.
[ ] 5. Organized all data into charts and tables.

_____ III. HAVE A PURPOSE _____

[ ] 1. Revised outline.
[ ] 2. Defined exactly what you hope to accomplish.
[ ] 3. Finished the statement- The purpose of this project is---.

_____ IV. PLAN YOUR PROJECT _____

[ ] 1. Designed your investigations, experiments, and observations.
[ ] 2. Defined "control group."
[ ] 3. Defined "dependent" and "independent" variables.
[ ] 4. Designed a flowchart and/or timeline.

_____ V. START EXPERIMENTATION _____

[ ] 1. Obtained equipment to measure and control variables.
[ ] 2. Controlled all variables except "dependent" variable.
[ ] 3. Obtained safety and/or live animal certification.

_____ VI. ANALYZE DATA _____

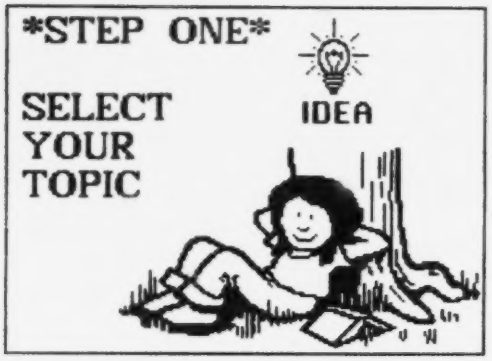
[ ] 1. Performed statistical and graphical analysis on data.
[ ] 2. Interpreted data. What does it mean?
[ ] 3. Determined if additional research is required.
[ ] 4. Formulated a conclusion by reviewing the results.
[ ] 5. Summarized work, and discussed it with advisor.

_____ VII. WRITE FINAL PAPER _____

_____ VIII. PREPARE AN EXHIBIT _____

_____ IX. ENTER SCIENCE COMPETITION _____

For details on completing this sheet, consult the manual.



This step may appear to be difficult, but is quite simple if you relate it to something you are interested in. You may be able to decide on a research idea because of your interest in one of the following areas:

[PROCESS] --> Electrolysis, Lasers, Propulsion, Photoelectricity, etc.

[CONCEPT] --> Radioactive Decay, Heat, Light, Germination, Diets, etc.

[LIFE] -----> Bacteria, Plants, Seeds, Lichens, Humans, Frogs, Mosses, etc.

[THINGS] --> Computers, Lasers, Spiders Webs, Rockets, Soil, etc.

[CHEMICALS] -> Dyes, Hormones, Enzymes, Catalyst, PVC, BPC, etc.

[CAREER] ----> Lawyer, Electrician, Technical Secretary, Scientist, etc.

A large percentage of the basic ideas for science projects come from magazines, journals, pamphlets, books, newspapers, etc. Below is a brief list to help you begin utilizing these resources. (See Appendix A for a list of possible research topics)

***** PAMPHLETS & BOOKLETS *****

"Science Fairs And Projects", $6.00 + $2.00 for postage. NSTA, 1742 Conn. Ave., NW; Washington 20009
"We've added plenty of project ideas, suggestions, etc. for student research ... ."

"The Science Workbook", $1.75 + $.80 for postage. Ohio Agricultural Education Service, Rm 254; 2120 Fyffe Rd., OSU; Columbus, OH 43210-1099
"A 109 page workbook containing 53 projects, in 20 subject areas, that can be used as science projects."

"Plants In The Laboratory,Monograph # 19", $7.00, NBTA, 11250 Roger Bacon Dr., Reston, Va 22090
"A compilation of laboratory experiments with plants"

"Chemistry Projects and Science Fairs", Free, Robert Varnerin, Mgr. of Education, CMA, 2501 M St. NW, Washington, DC 20037
"A 12 page booklet including dections on obtaining materials, performing experiments, writing a report and preparing a display."

********** BOOKS **********

"Experimenting With Plants", Joel Beller, $6.95 (paper) Simon & Schuster, 1985
"The ideas for research are nicely openended: How long do organic insecticides remain effective ?, etc. The book contains dozens of such ideas."

"Fair Abstracts", $5.00, Available Nov., 1986; Science Service, 1719 N. Street, NW, Washington, DC 20036
"A book with abstracts of research projects of the more than 600 finalist in the 37th International Science Fair. Other issues also available."

"Bulletin of the S. C. Academy of Science", $7.00; J.L. Safko, USC, Columbia, S.C. 29208
" Abstracts of research projects of the more than 400 participants in the 1986 S.C. Jr. Academy competition. Back issues also available."

"Science Projects With Computers and Electrons", Alfred Bender; $3.95 (paper) Arco Publishing Co. Inc., 219 Park Ave. South, New York, NY 10003

"Nuts and Bolts", Deman & McDonald, $4.95 , The Science Man Press, Harvard Heights, Illinois 60656
"The writing , illustrations and design are superior: steps for conducting a project are comprehensive and clear... ."

"Winning With Science", William Lowery, $7.95 + $1.00 shipping; Loiry Publishing House, 535 S. Orange Ave., Suite 6, Sarasota, Fla. 33577
"The complete guide to science research and projects for students"

"So You Want To Do A Science Project", Joel Beller, $9.95; Arco Publishers, 219 Park Ave. S., NY,NY 1003
"Sample projects, topics research and documentation techniques, and informations sources are plentiful."

>> Oldies But Goodies << You can try the publishers, for the following but your best bet is a used paperback book store.

"Science Projects Handbook", Science Service, 1719 N. St., NW, Washinton, DC 20036.
I used this when I did my high school science project. It's the "bible". Try to find it.

" The Amateur Scientist" , Scientific American, Inc. , 415 Madison Ave., NY,NY 10017
A compilation of some of the better amateur projects published in the "Amateur Scientist" column of Scientific American magazine. Projects are from all areas of science.

********** MAGAZINES **********

For excellent topic sources, check your school, public and college for these publications.

[1] The Science Teacher

[2] Journal Chemical Education

[3] Scientific American

[4] The Physics Teacher

[5] Chem-Matters

[6] Discover

[7] Science Digest

[8] Electronic Learning

[9] InCider

[10] Computers in Science & Math

[11] Omni

[12] Popular Electronic

[13] Natural History

[14] Science

[15] Journal College Science Teaching

[16] BASE - I highly recommend this one. It publishes the original work of high school age scientists. Order from- Editorial Office, Alin Foundation Press. 1 Alin Plaza, 2107 Dwight, Berekely, Ca. 94704-2062

[17] CHEMISTRY - You will probably have to dig this one out of the library basement or off microfilm. The "Lab-Bench" section is an unbeatable resource.

[18] Indexes - A time saver is to consult compiled indexes of the above magazines. Most yearly indexes are printed in the December issue.

Scientific American has a bound volume of indexes for the "Amateur Scientist" section.

The Journal of Chemical Education has bound volumes of indexes for blocks of years.

Don't forget the Reader's Guide.

******* ADDITIONAL SOURCES *******

The following organizations have booklets and pamphlets that might help you choose a science project. Write those which specialize in your area of interest.

Manufactoring Chemist Association
1825 Conn. Ave., NW
Washington, D.C. 20009

National Audubon Society
1130 5th Ave.
New York, New York 10028

National Wildlife Federation
1412 16th Street, NW
Washington, D.C. 20036

World Book Science Projects
Field Enterprises Educational Corp.
Station 8, Merchandise Mart
Chicago, Ill. 60654

Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

Cheveron Chemical Company
Public Relations
200 Bush Street
San Francisco, California 94120

DO NOT HESITATE TO WRITE A SCIENTIST OR COMPANY FOR HELP !!!

K. I. S. S.

Its decision time ! Once you have decided on an idea or area of interest, choosing a research topic is fun . Choose a topic that- (A) is of interest to you. (B) Limited in scope (C) Can be completed.

******** ASSIGNMENT I ********

Worksheet I is designed to help you choose a final project idea. Complete it using the sample below and TURN IN BEFORE DUE DATE.

}}}} KEEP IT SO SIMPLE {{{{

WORKSHEET I - Selecting A Topic

I- Describe the area of interest in which you would like to do research.

" Because of a lab I did in Biology last year, I would like to study seed germination and growth."

II- List the factors (independent variables) you can control which could affect the outcome (dependent variables) of your research.

(1) Carbon Dioxide (2) Temperature (3) Light (4) Moisture (5) Nutrients

III-What noticeable and measurable characteristics (dependent variables) would possibly be affected by the independent variables.
(1) Growth (2) Respiration (3) Color (4) Moisture Content

IV- Using the variables in (II) & (III), form some possible "cause and effect" relationships.
(1) Light on respiration (2) Light on growth (3) Moisture on respiration (4) Temperature on color. (5) Other

V- Using (IV), list possible projects.
(1) Effects Of Light Quality On Seed Respiration. (2) The Effect of Moisture On Seed Respiration

VI- Of those listed in (V), which would you like to do ? Effects Of Light Quality On Seed Respiration.

WORKSHEET I ----- >> SELECT YOUR TOPIC

Name _____ Class _____

I- Describe the area of interest in which you would like to do research.

_____

_____

_____

II- List the factors (independent variables) you can control which could affect the outcome (dependent variables) of your research.

1._____ 2._____

3._____ 4._____

5._____ 6._____

III- What noticeable and measurable characteristics (dependent variables) would possibly be affected by the independent variables?

1._____ 2._____

3._____ 4._____

5._____ 6._____

IV- Using the variables in II and III, form some possible "Cause" and "Effect" relationships.

Cause_1_____ Effect_1_____

Cause_2_____ Effect_2_____

Cause_3_____ Effect_3_____

V- Using the "Causes" and "Effects" listed in IV, create some possible science projects.

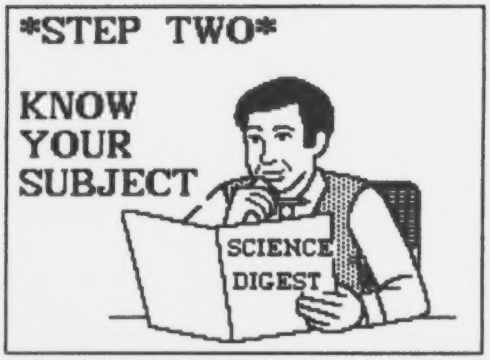
1._____

2._____

3._____

4._____

VI- Which project would you like to do?

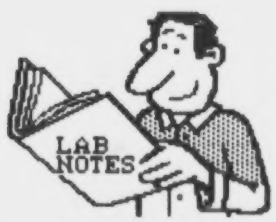


Once you have a topic in mind, continue to READ-READ-READ ! Reviewing related literature is basic to all research and will provide you, the researcher, with additional knowlege and insight into your topic. It will help you organize the concepts and principles fundamental to your research. These related sources support the study and documents accepted facts, concepts and processes upon which the research is is based.

TAKING NOTES

When taking notes two procedures should be followed:
[1] The reference information should be correctly recorded so proper documentation of sources can be made and appropriate credit can be given the author.

[2] The notes should correlate to the general outline and theme of your paper so that they can be included easily.



* NOTEBOOKS *

Notes are traditionally taken on 3 x 5 cards. However, as a scientist, you may find it more useful to keep all of your notes in a note-book. Follow these suggestions for keeping a useful notebook:

[1] Your notebook should be sturdy, and permanently bound. (DO NOT use a looseleaf notebook.) Use INK.

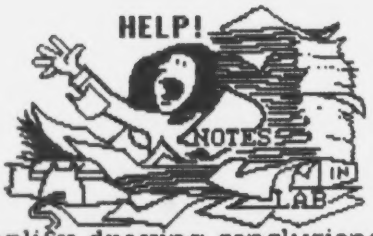
[2] Date all notes on each page.

[3] Complete notes are an absolute necessity. Be concise and clear.

[4] When recording data draw a table or chart and fill it in.

[5] Write up all work. Failures may prove valuable later. Do not erase ! If you feel something is an error, mark void across it and continue.

[6] All questions, observations, etc., should be written in your notebook.



ORGANIZE YOUR NOTES !!

Organized notes speed up the paper writing process, simplify drawing conclusions, and earn high grades on your notebook. A typical page from your notebook should follow the format below when recording information from a publication.

DATE - 7/22/86

PROJECT TITLE - Light Quality On Respiration

AUTHOR - R.G. Stanley and W.L. Butler

ARTICLE TITLE- Life Processes of the Living Seed

PUBLISHED IN - Seeds-The Yearbook of Agriculture

DATE - 1978

PAGE(S) - 93

PUBLISHER - The U.S. Government Printing Office, Washinton, D.C.

USEFUL MATERIAL - " growth of seeds and plants is affected by light in the red part of the spectrum. The pigment that mediates these effects was extracted from seeds and in seedlings in 1959.
It is a soluble protein in cells in very low concentrations. This pigment acts as an enzyme in some reactions so basic to plant development that it controls germination of certain seeds and several other phenomena of the growth and development in plants.
The pigment exist in two forms. One absorbs red light with an absorption maximum at wavelength of 660 millimicrons. The other absorbs far-red light at a maximum of 730 millimicrons. When the pigment absorbs light in one form, it is converted to the other chemical form.

660 millimicrons
P660 ----------> P730
P730 <---------- P660
730 millimicrons

SIGNIFICANCE TO PROJECT - (1) Confirms that light of certain frequencies affects germination. (2) Doesn't comment on frequencies of light in the blue and ultraviolet range. (3) Gives basic explanation as to why light affects germination.

******* ASSIGNMENT II *******
When you have found several literature sources, fill out one Worksheet # 2 for the number of resources required by your teacher. Turn these in by the due date listed on your checklist.(Page 2)

WORKSHEET II ----- >> KNOW YOUR TOPIC

NAME _____ CLASS _____

PROJECT TITLE _____ DATE _____

ARTICLE TITLE _____

AUTHOR(S) _____

PUBLICATION _____

DATE _____ PAGE(S) NUMBER(S) _____

PUBLISHER _____

USEFUL MATERIAL _____

SIGNIFICANCE TO PROJECT _____

To be a success, a science project must have a definite purpose or goal - what question(s) are you trying to answer? What experimental data are you seeking? You can only get limited answers in doing one science project. Be sure you have limited your purpose to a goal you can attain. (i.e , "The Effects of Light Quality on Seed Respiration" may be to broad, where as , "The Effects of 6000 A and 4000 A Light on the Respiration of Corn Seeds" is much more definite.

A major mistake by students is that of choosing a purpose that involves more information and more work than they understand and complete in the time available. A second common mistake is that of choosing a project that requires skills and materials that are unavail -able .

Dr John Y Dempsey clearly states in " A Guide To The Development Of Research Projects In High School Science" (Available from - Graham Resources, Inc. ; 3510 N. Causeway, Metairie, La. 70011; Cost-Unknown) that-

"Generally the objective can be and should be stated in one sentence. Difficulty in stating the objective in one sentence indicates the need for further refinement and narrowing of of the planned study. Several basic forms can be used to state the objective/purpose.

[1] The purpose of this research is to investigate_____ with respect to (1) _____, (2)_____. and (3) _____.

[2] The purpose of this research is to compare _____ with respect to (1)_____, (2)_____, and (3)_____.

[3] The purpose of this research is to determine the relationship between _____ and _____ with respect to (1) _____, (2) _____, and (3) _____.

[4] The purpose of this research is to determine the effect of _____ on _____with respect to (1) _____, (2) _____, and (3) _____.

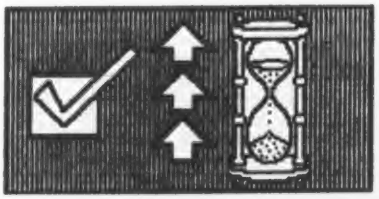
If your objective/purpose is well - worded, you should have no difficulty in formulating a title. Your title should be sufficiently descriptive of your purpose without being to long. Try writing several titles on paper before you come to any decision.

Following form # 4, the pupose of the light and respiration project might read -

" The purpose of this research is to determine the effect of 4000 and 6000 angstrom wavelengths of light on the germination of corn seeds with respect to respiration rate."

******* ASSIGNMENT III *******

Your teacher has given you a date that you should have the exact purpose of your project formulated. If you have difficulty completing Worksheet III before this date, ask for help. DON'T BE LATE !!!!



At this point in your research you should have completed and turned in ASSIGNMENTS I thru IV. Check off the following to make sure-

- [ ] Filled in due date on "Check List"
- [ ] Selected a topic area. "Worksheet I"
- [ ] Found references. "Worksheet II"
- [ ] Written a purpose."Worksheet III"

"SCIENCE is a process in which you can do a hundred things right and only one thing wrong, and still come out with the wrong answer."

IN MEMORY OF THE CREW OF CHALLENGER

" O to realize space ! The plenteousness of all, that there are no bounds.
To emerge and be of the sky, of the sun and moon and flying clouds, as one with them."

W. Whitman

WORKSHEET III ----- >> HAVE A PURPOSE

NAME _____CLASS_____

PROJECT TITLE _____DATE _____

I- Using the four basic forms discussed in STEP THREE of this manual, write four different purposes your research could possibly have.

Purpose #1 _____

_____

_____

Purpose #2 _____

_____

_____

Purpose #3 _____

_____

_____

Purpose #4_____

_____

_____

II- Which of these best describes what you would like to accomplish with your research ?

_____

_____

_____

III- Now that you have precisely defined the goal of your project, write the title of the project that will go on the title page of your report and on your backboard.

_____

_____

STEP FOUR

PLAN YOUR PROJECT

" THE MOST INCOMPREHENSIBLE THING ABOUT THE UNIVERSE IS THAT IT IS COMPREHENSIBLE "
-- Albert Einstein

For your project to be a success you will have to do some planning. Your first research project may appear to be an impossible task when you begin. However, if you will "do your project on paper" first, many of what appeared to be obstacles will disappear.

Initially you should answer some fundamental questions.

[1] Where will I do my project ?
[2] What type of equipment will I need and is it available ?
[3] Are there foreseeable problems ?
[4] How much will it cost and can I afford it ?
[5] Do I clearly understand what I'm trying to accomplish?

Your next task is to anticipate a sequence of steps that may lead you to your purpose and to follow these steps even though the chances are good that changes will have to be made as you proceed with your research .

Some planning techniques might include FLOWCHARTING, a CHECKLIST of steps in sequence, and TIMELINE charts. Below is a CHECKLIST for the hypothetical project dealing with the respiration of corn seeds and light frequency. Examples of the other two techniques are given on the following pages.

" DON'T PUT THE HORSE BEFORE___"

***** ASSIGNMENT IV ******

Complete Worksheet IV. You cannot foresee every problem and will have to alter some of your original plans. However, a flowchart and/or a time line will reduce unforeseen problems.

" The Effects Of 6000 A And 4000 A Light On The Respiration Rate Of Yellow Dent Corn Seeds."

Experimental Plan Check List

[ ] Sept. 9th - "Select Your Topic"
[ ] Sept. 16th- "Know Your Subject"
[ ] Sept. 23rd- "Have A Purpose"
[ ] Sept. 23rd- SCJAS grant proposal
[ ] Sept. 30th-Flowchart Worksheet 4

[ ] Oct . 1st- Order light filters and Dent Corn. Get Volumeter from school.

[ ] Oct . 15th- Begin experimentation. Soak two sets of 50 corn seeds on layers of wet towels (See "Biological Science - Interaction of Experiments and Ideas; p51) in plastic petri dishes. Expose one set to 6000A light and the other to 4000A light for 24 hours.

[ ] Oct. 16th - Choose 40 corn seeds from each of the two sets. Measure the volume of each group and record in notebook. Return seeds to their petri dishes and continuing exposing them to light for an additional 24 hours.
[ ] Oct. 17th - Set up volumeter as described in BSCS text, and record respirations. Submit Worksheet #5.

[ ] Oct. 18th - Perform data analysis on results. (See STEP 6) Try to obtain good computer program to perform analysis. Complete Worksheet #6.

[ ] Oct. 20th - Discuss results with teacher. If data is inconclusive, rerun experiment.
[ ] Oct. 22nd - Begin writing rough draft of paper. Follow guidelines in science project manual.

[ ] Nov. 3rd - Turn in rough draft along with Worksheet # 7.

[ ] Nov. 24th - Turn in corrected finished paper.

[ ] Dec. 1st - Rough draft of Westinghouse application due.

[ ] Dec. 8th - Final Westinghouse application.

[ ] Jan. 10th - Abstract & Paper due to SCJAS.

[ ] Jan. 12th - Sketch of backboard and Worksheet # 8 due.
[ ] Jan.26th - Backboards due.

[ ] Feb. 2nd - Enter school fair.

[ ] March 2nd - Audio-visuals and Worksheet # 9 due.

[ ] March 9 thru 16 - Papers will be given in class.

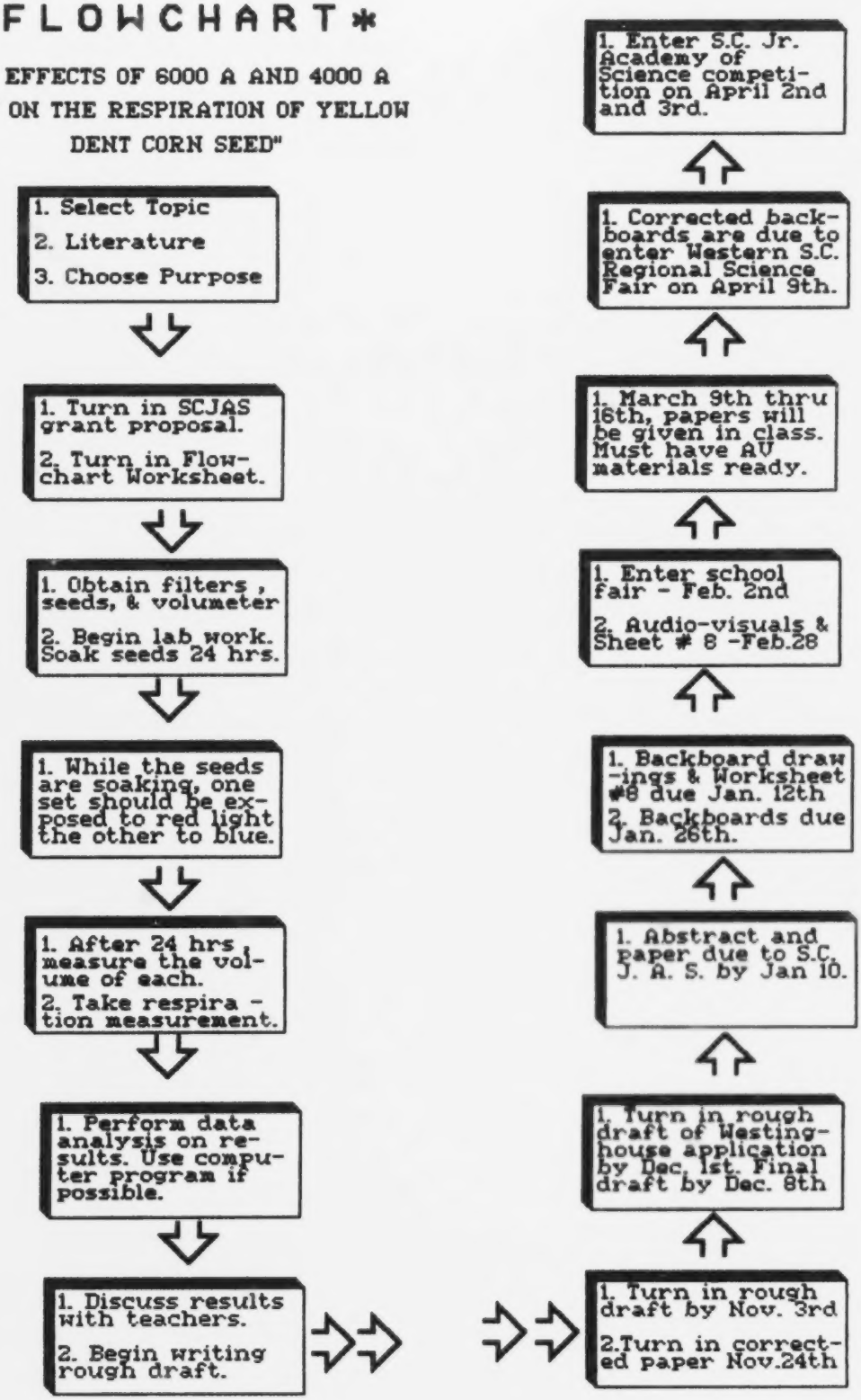
[ ] April 1st - Corrected backboards are due. Send application to enter regional science fair.

[ ] April 2nd and 3rd - Compete in South Carolina Junior Academy of Science competition.

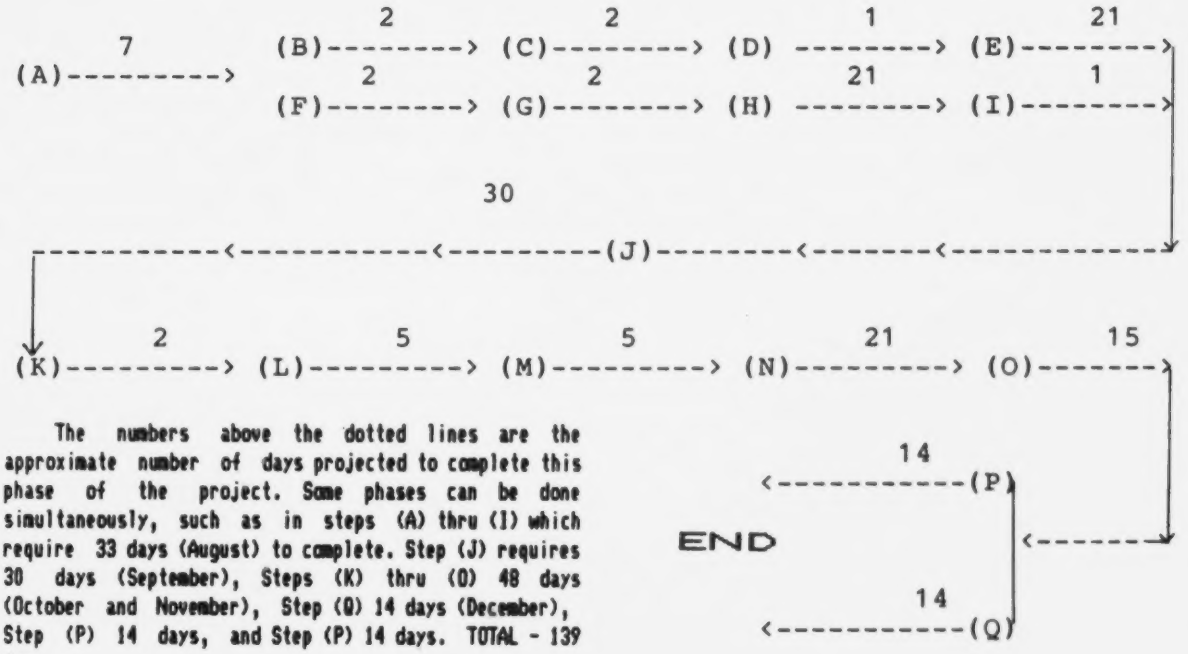
[ ] April 9th & 10th - Compete in Western South Carolina Regional Science Fair.

* FLOWCHART *

"THE EFFECTS OF 6000 A AND 4000 A LIGHT ON THE RESPIRATION OF YELLOW DENT CORN SEED"


1. Select Topic
2. Literature
3. Choose Purpose
1. Turn in SCJAS grant proposal.
2. Turn in Flow-chart Worksheet.
1. Obtain filters , seeds, & volumeter
2. Begin lab work. Soak seeds 24 hrs.
1. While the seeds are soaking, one set should be ex-posed to red light the other to blue.
1. After 24 hrs , measure the vol-ume of each.
2. Take respira - tion measurement.
1. Perform data analysis on re-sults. Use compu-ter program if possible.
1. Discuss results with teachers.
2. Begin writing rough draft.
1. Turn in rough draft by Nov. 3rd
2.Turn in correct-ed paper Nov.24th
1. Turn in rough draft of Westing-house application by Dec. 1st. Final draft by Dec. 8th
1. Abstract and paper due to S.C. J. A. S. by Jan 10.
1. Backboard draw -ings & Worksheet #8 due Jan. 12th
2. Backboards due Jan. 26th.
1. Enter school fair - Feb. 2nd
2. Audio-visuals & Sheet # 8 -Feb.28
1. March 9th thru 16th, papers will be given in class. Must have AV materials ready.
1. Corrected back-boards are due to enter Western S.C. Regional Science Fair on April 9th.
1. Enter S.C. Jr. Academy of Science competi-tion on April 2nd and 3rd.

* TIME LINE *

"The Effects Of 6000 A And 4000 A Light On The Respiration Of Yellow Dent Corn Seed"

The numbers above the dotted lines are the approximate number of days projected to complete this phase of the project. Some phases can be done simultaneously, such as in steps (A) thru (I) which require 33 days (August) to complete. Step (J) requires 30 days (September), Steps (K) thru (O) 48 days (October and November), Step (Q) 14 days (December), Step (P) 14 days, and Step (P) 14 days. TOTAL - 139 days

(A) Select topic. See title above.
(B) Identify independent variables (Light, moisture, nutrients, seed type).
(C) Select independent variable to study (Light).
(D) Be specific on independent variable (6000 & 4000 A light).
(E) Obtain instrument for measuring and controlling variable (Filters).
(F) Identify dependent variables. (Germination, respiration,growth).
(G) Select dependent variable to measure (Respiration).
(H) Obtain instrument for measuring dependent variable (Volumeter).
(I) Identify control (Seeds will be compared against each other).
(J) Begin experimentation and data collection.
(K) Identify necessary data analysis to be performed (Statistical -variance & chi-squared).
(L) Method of data analysis (Appleworks spreadsheet).
(M) Draw conclusions.
(N) Write Paper (Rough draft by Nov.3rd, finished paper by Nov.24th).
(O) Enter Westinghouse (By December 15th, abstract to SCJAS by Jan.10th).
(P) Construct backboard (Enter school fair Feb. 2nd & regional science fair April 9th).
(Q) Enter S.C. Jr. Academy of Science (April 2nd and 3rd).

WORKSHEET IV ----- >> PLAN YOUR PROJECT

NAME _____ CLASS _____

PROJECT TITLE _____ DATE _____

I- List below, in sequential order, the steps necessary to complete your project. Use more than one sheet if necessary. Using this list, create either a "FLOW CHART" or "TIMELINE" of your planned research.

Step 1. _____

Step 2. _____

Step 3. _____

Step 4. _____

Step 5. _____

Step 6. _____

Step 7. _____

Step 8. _____

Step 9. _____

Step 10. _____

Step 11. _____

Step 12. _____

Step 13. _____

Step 14. _____

Step 15. _____

Step 16. _____

Step 17. _____

Step 18. _____

Step 19. _____

Step 20. _____

STEP FIVE

START EXPERIMENTS

By this time you should have decided the role variables will play in your research. In Step I you identified the "independent" and "dependent" variables. Two other type variables with which you must be concerned are "controlled" variables and "control groups". Let's take a closer look at each of these four types.

INDEPENDENT

Any factor which you control and vary during your research is called an "INDEPENDENT VARIABLE". Usually there is only one independent variable in high school level projects. Two or more are too complicated. In your research you will change something to observe what will happen. The thing you change is the "INDEPENDENT VARIABLE".

DEPENDENT

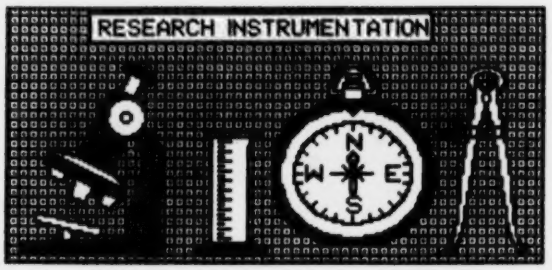
You change "something" to observe what will happen. This "something" may cause "something else " to happen. This "something else" is the DEPENDENT VARIABLE. The result obtained after setting the INDEPENDENT VARIABLE is the DEPENDENT VARIABLE.

CONTROLLED

Factors that are not to be studied in the research but could affect the results if not held constant, are called CONTROLLED VARIABLES.

CONTROL GROUPS

Most research is designed to determine "cause and effect" - the effect the INDEPENDENT VARIABLE has on the DEPENDENT VARIABLE. A CONTROL GROUP is free of any change free of the INDEPENDENT VARIABLE. (i.e. one group of seeds is treated with a hormone (INDEPENDENT VARIABLE) and one is not (CONTROL).



Manipulating the independent variable, measuring the dependent variable, and controlling all other variables require the use of a wide range of laboratory instruments.

In the following table is a list of properties, the metric unit of measurement followed by its abbrevia -tion and some of the instruments used to measure the property.

T A B L E I

LENGTH - (meter(m) - meter stick, tape measure, micrometer, vernier caliper

MASS - (kilogram(kg)- spring balance, lever-arm balance, inertial balance.

TIME - (second(s) - stopwatch

TEMPERATURE - (centigrade(C) - thermometer, thermocouple, thermistor, pyrometer

DENSITY - (kg/mxmxm) - pycnometer, hydrometer, balance & meter stick,

AREA - (mxm) - planimeter(irregular), meter stick & formula (regular)

VOLUME - (mxmxm) - pipette, graduated cylinder, burette

VELOCITY - (m/s) - speedometer, anemometer, stopwatch & meter stick

ANGLE - (degrees(o) - sextant, protractor, transit

FORCE - (Newton(n) -spring balance, scales

PRESSURE - (Pascal(N/mxm) - barometer, manometer, mechanical pressure gauge.

ELECTRICAL POTENTIAL - (Volt(V) - voltmeter

ELECTRICAL CURRENT - (Amperes(amp)- ammeter

ELECTRICAL RESISTANCE- (Ohms(Ω) - Wheatstone bridge, ohmmeter

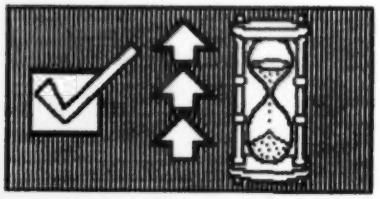
HEAT - (joule(j) - calorimeter

LIGHT INTENSITY - (candela(c) - photometer, photoelectric cell

SOUND INTENSITY - (decibel(db) - audiometer

ACIDITY - (pH) - pH meter

HUMIDITY - (%) - hygrometer

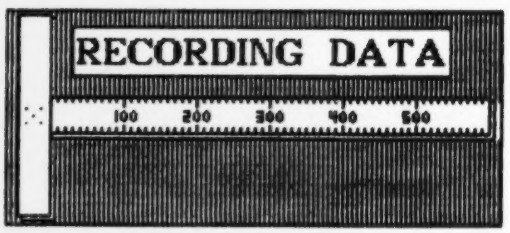


At this point you should have completed and turned in ASSIGNMENTS I thru V. Check off the following to make sure-

- [ ] Filled in due date on "Check List"
- [ ] Selected a topic area. "Worksheet I"
- [ ] Found references. "Worksheet II"
- [ ] Written a purpose."Worksheet III"
- [ ] Research planned. "Worksheet IV"
- [ ] Identified variables

REVIEW OF VARIABLES

INDEPENDENT - Controlled variation
DEPENDENT- Uncontrolled variation
CONTROLLED - No variation
CONTROL GROUP - Comparison standard



As a young researcher you will soon discover that in making measurements, you will encounter some difficulties that must be faced if the data from your research are to have significance.

The difficulty lies in the fact that most measurements are uncertain. This uncertainty has two main causes: (1) the measuring limitation of the instrument used (2) your skill as a scientist. However with an understanding of a few basic ideas in data analysis and measuring techniques you can handle these problems and produce meaningful research results.

>> ACCURACY AND PRECISION<<

All measurements in science research should be in metric units and obtained using instruments that allows the proper "accuracy" and "precision". Although these two terms are frequently interchanged in daily conversation, scientists make a definite distinction between them.

"Accuracy" refers to how close a measurement is to the accepted value for a specific physical property. "Precision" is the agreement among several measurements made using the same techniques and instrument; a measure of reproducibilty.

PRECISION

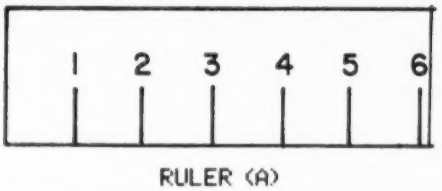
Precision can be expressed as a "tolerance", a "deviation" or with "significant figures".

The degree of precision obtainable from an instrument is its "tolerance" and is determined by the nature of the instrument. A platform balance for example is said to have a tolerance of 0.1 gram. This means that the balance can be used to repeatedly measure an unknown mass to within one tenth of its "actual mass". The manufacturer is assuming of course that the person using the balance can do so correctly.

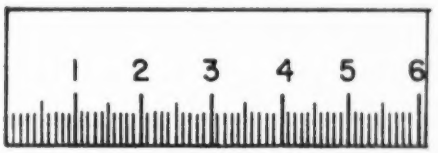
The simplest measure of precision is the AVERAGE DEVIATION, which will be discussed in detail in Step # VI.

"Significant figures" are a direct result of the instrument being used. Each instrument has a scale designed to measure a quantity to a certain number of decimal places. These decimal places are called "significant digits". The number of significant figures that can be obtained using a particular instrument is equal to the number of "known digits", plus one estimated digit.

Below are sections of two different metric rulers. Ruler (A) is marked off in major graduations of centimeters (one known digit), Ruler (B) has major graduations of centimeters and millimeters (two known digits). Ruler (A) can be used to measure two significant digits (one known and one estimated) and Ruler (B) to measure 3 significant digits. (Two known and one estimated) Remember - EVERY GOOD MEASUREMENT CONTAINS ONLY ONE ESTIMATED DIGIT.



RULER (A)



RULER (B)

ACCURACY

Precise measurements, however, are not necessarily accurate. The "ACCURACY" indicates the agreement of the measurement with the accepted value of the quantity. Accuracy is expressed in terms of the error, the experimentally determined value minus the accepted value. (See Step VI- Analyze Data)

"WHERE THE TELESCOPE ENDS, THE MICROSCOPE BEGINS. WHICH OF THE TWO HAS THE GRANDER VIEW ?"

Victor Hugo
"Les Mis'erables"

Working in the laboratory is an interesting and rewarding experience. During your research you will be working with equipment and materials that can cause injury if they are not handled properly. However, the laboratory is a safe place to work if you are careful. Accidents do not just happen, they are caused by haste, carelessness and not following safety rules and practices. Before beginning your lab work, read the below safety rules, learn them and follow them.

*** GENERAL RULES ***

1. EXPERIMENTATION IS SERIOUS WORK - NOT HORSE-PLAY.

2. PERFORM ONLY THOSE EXPERIMENTS PREVIOUSLY APPROVED BY YOUR TEACHERS.

3. KEEP YOUR WORK AREA CLEAN AND UNCLUTTERED.

4. WEAR SAFETY GLASSES AND APRONS AT ALL TIMES.

5. LOCATE THE FIRE EXTINGUISHER AND SAFETY SHOWER BEFORE YOU BEGIN WORK.

6. HAVE ALL APPARATUS CHECKED OUT BY YOUR TEACHER BEFORE USING IT.

7. USE THE PROPER TOOL TO DO A JOB.

8. KEEP COMBUSTIBLE MATERIALS AWAY FROM FLAMES.

9. NEVER PUT YOUR FACE NEAR AN OPEN CONTAINER OF CHEMICAL.

10. CLEAN UP ALL SPILLS IMMEDIATELY.

11. REPORT ALL ACCIDENTS TO YOUR TEACHER AND PARENTS IMMEDIATELY.

12. EXPERIMENTS EVOLVING FUMES SHOULD BE DONE IN A FUME HOOD.

*** BIOLOGICAL PRECAUTIONS ***

1. USE ONLY NONPATHOGENIC VARIETIES OF BACTERIA.

2. SEAL ALL PETRI DISHES WITH TAPE.

3. WEAR RUBBER GLOVES WHEN WORKING WITH BACTERIA.

4. KILL ALL CULTURES BEFORE DISPOSING OF THEM. THIS CAN BE DONE EASILY IN AN AUTOCLAVE.

5. MAKE SURE THAT YOU FOLLOW ALL RULES FOR WORKING WITH VETERBRATES. ASK YOUR TEACHER. ALSO SEE APPENDIX (B) FOR A SAMPLE FORM REQUIRED BY THE INTERNATIONAL SCIENCE FAIR.

*** CHEMICAL PRECAUTIONS ***

1. READ AND DOUBLE CHECK LABELS ON ALL CHEMICAL BOTTLES. TAKE ONLY AS MUCH AS YOU NEED.

2. AVOID TOUCHING CHEMICALS WITH YOUR HANDS.

3. DO NOT USE UNLABELED CHEMICALS.

4. DO NOT RETURN UNUSED CHEMICALS TO STOCK BOTTLES.

5. NEVER TASTE CHEMICALS.

6. AVOID USING KNOWN CARCINOGENIC CHEMICALS. (ASK YOUR TEACHER)

7. POUR ACID IN WATER-NEVER WATER IN ACID.

8. NEVER MIX CHEMICALS WITHOUT PRIOR CLEARANCE FROM YOUR TEACHER.

*** OTHER PRECAUTIONS ***

1. DO NOT VIEW LASERS, THE SUN, OR OTHER LIGHT SOURCES DIRECTLY.

***** ASSIGNMENT V *****

Complete WORKSHEET V ! Donot begin your experimentation until your teacher has signed the "APPROVAL TO PROCEED" line. Have fun !!!!

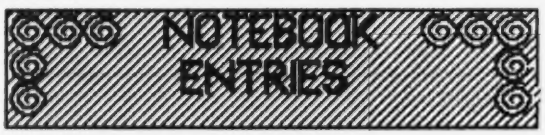


TABLE II is an example of a simple format used to record data in a note-book. It was designed for recording the respiration rates of corn seeds exposed to 6000 A and 4000 A light. ("A" stands for angstrom).

The title of the table (1) names the dependent variable first and concludes with the independent variable. (2) clearly identifies the relationship between the two variables.

RESPIRATION OF CORN SEEDS EXPOSED TO 6000A AND 4000A LIGHT		
EXPERIMENT NUMBER	MLS OF OXYGEN/HOUR	
	6000A (RED)	4000A (BLUE
1	0.31	0.21
2	0.24	0.20
3	0.29	0.21
4	0.24	0.22
5	0.34	0.25
6	0.24	0.24
7	0.24	0.22
8	0.30	0.21
9	0.28	0.25
10	0.22	0.19

WORKSHEET V ----- >> START EXPERIMENTS

NAME_____CLASS_____

PROJECT TITLE _____DATE _____

I- EQUIPMENT

(1) Describe how you will control the dependent variable . Include the name of any instruments that will be used and the number of significant figures it will measure.

(2) Describe the instrument to be used to measure the independent variable. How many significant figures will it measure ?

(3) List any other variables that must be controlled and explain how you will keep them constant.

(4) If you are using a control group - describe it.

II - SAFETY

(1) List any potential hazards that may be encountered in your research.

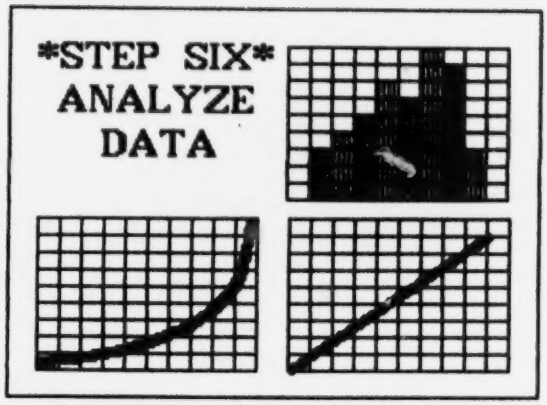
III - TEACHER PERMISSION OR RECOMMENDATIONS - After reading the above report and inspecting your research apparatus, materials and method , my recommendation is as follows:

( ) You MAY NOT proceed with your experimentation until -

( ) You MAY proceed with your experimentation as described above.

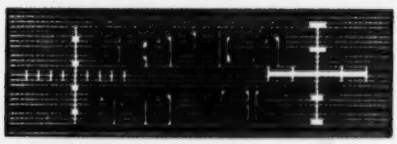
APPROVAL TO PROCEED _____

DATE_____



As mentioned on page 14, the purpose of most research is to determine if there is a "cause and effect" relationship between the independent and dependent variables. Whether a relationship, pattern or regularity exists may not be obvious from looking at your experimental data.

This search for some sort of trend or consistency within data can be made easier using the techniques of graphical and statistical analysis.



To better understand the relationship between the dependent and independent variables it sometimes helps to graph the data. Graphing is especially useful when the value of the dependent variable is measured at several values of the independent variable. Lets look at a hypothetical example.

A student wants to determine if there is a cause and effect relationship between the volume that a gas occupies and the pressure it creates. The volume (independent variable) will be changed and the resulting pressures (dependent variable) will be measured. The amount of gas and the temperature will be held constant (constant variables). The volume will be adjusted to five different values and resulting pressures recorded as shown in Table III .

TABLE III

PRESSURE OF ARGON AT VARIOUS VOLUMES	
P, cm Hg	V, cm^3
90.0	21.0
74.4	25.0
61.0	31.8
45.5	41.1
32.0	60.1

This data was then plotted using the following standard guidelines for producing useful graphs :

))GUIDELINES FOR PLOTTING GRAPHS ((

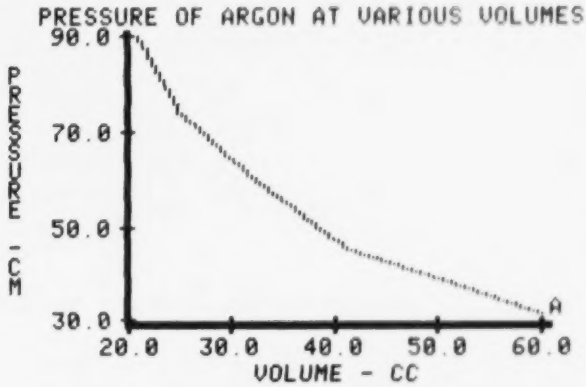
1. THE INDEPENDENT VARIABLE (VOLUME) IS PLOTTED ON THE (X) HORIZONTAL AXIS.

2. THE DEPENDENT VARIABLE (PRESSURE) IS PLOTTED ON THE (Y) VERTICAL AXIS.

3. BOTH AXIS ARE CLEARLY LABELLED.

4. VALUES ON THE (X) AXIS SHOULD INCREASE FROM LEFT TO RIGHT AND VALUES ON THE (Y) SHOULD INCREASE FROM BOTTOM TO TOP. BEGIN (Y) AT (0) IF POSSIBLE.

When the data in Table III are plotted, the below graph results.



If the points had been scattered and formed no apparent "line" or pattern, then there may be no cause and effect relationship between the variables, and the experiment should be rethought and rerun.

In this case a "smooth" line is found to connect the points on the graph, indicating a cause and effect relationship. At this time the data should be refined further by identifying this relationship and if possible write it in equation form. A student with a good high school math background can often recognize the nature of a relationship by looking at the shape and position of a graph line.

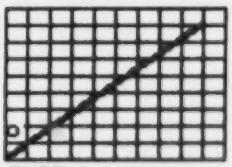
The diagrams on the next page show some of the more common relationships in graphical form. A description of each relationship is also given. These shapes are very useful in deriving a general equation that relates two sets of data. This process is called "curve fitting".

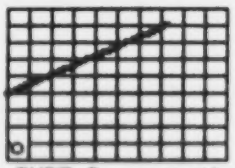
Comparing the above graph with these diagrams it becomes obvious that the "cause and effect" relationship between the pressure and volume of argon is similiar to type #7 or an "inverse proportion" The general equation of this type relationship is that of a hyperbola and has the form - $y = m(1/x) + b$. The (m) and intercept (b) can be found using mathematics or a computer and required software.

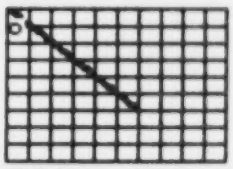
STANDARD RELATIONSHIPS

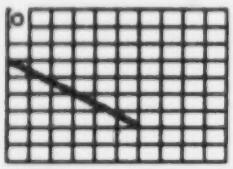
The below diagrams show some common relationships expressed in graphical form. An examination of these graphs will reveal something special about each type. A few comments follow. Check with your teacher and consult your math book for additional characteristics. (NOTE- the little "o" locates the origin)

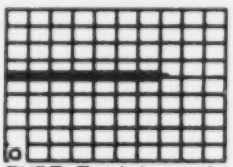
Type 1 - A direct proportion. Slope is (+) and constant.
Type 2 - No proportionality. Slope is +
Type 8 - If y/x2 is constant, the curve is parabolic and the equation y = ax2 is quadratic.
Type 9 - "y" increases as "x" increase. A parabola if y2/x is constant.

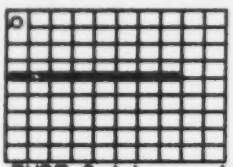

TYPE 1 y=mx

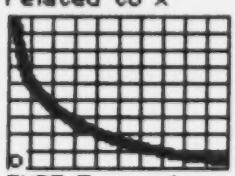

TYPE 2 y=mx+b

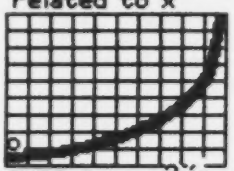

TYPE 3 y=-mx

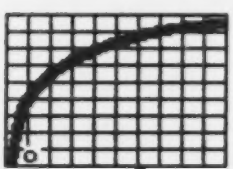

TYPE 4 y=-mx + b

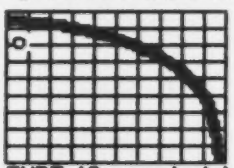

TYPE 5 (+)y not related to x

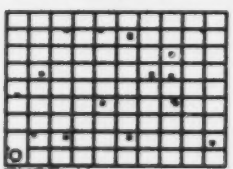

TYPE 6 (-) y, not related to x


TYPE 7 y = 1/x


TYPE 8 $y=ax^2$ if y/x2 is constant


TYPE 9 $y^2=ax$


TYPE 10 y gets(-) as x increases


TYPE 11 random no relationship

TYPE 12-sinusoid if y=A sin x

MICROCOMPUTER COMPUTER CURVE FITTING

A rapid method for determining the equation that best describes a set of data is to use a "curve fitting" piece of software and a microcomputer. The microcomputer will rapidly take two sets of data and fit it to the best line. This method is quicker and in most cases the parameters necessary to write the equation for the relationship between the dependent and independent variables are clearly displayed. For example - the PRESSURE vs VOLUME graph above was plotted on a IMAGEWRITER printer using an APPLE IIE computer and a piece of software called " MECC GRAPH " . The equation of the resulting hyperbola was found using "GRAPHICAL ANALYSIS". (Appendix C contains a list of useful software for analyzing data)

The equation that best describes the above graph is:

P(pressure) = 1770/V(volume) + 4

Curve fitting is a technique in which one attempts to find the best match between an equation for a line or a curve and some experimental data . The line can either be linear or curved. Because of the desire to express the relationship between two variables as a mathematical function, curve fitting is an important computer-based activity of the successful scientist.

STATISTICAL ANALYSIS

For some types of data the methods of graphical analysis discussed above are insufficient or not applicable, and analysis using statistics is more appropriate.

The method by which you analyze your data will depend greatly upon your mathematical background, as well as the data to be analyzed. However, there are two basic characteristics used to analyze groups of data that are easy to understand and are relatively easy to calculate. These two characteristic are (A) CENTRAL TENDENCY and (B) DISPERSION (SPREAD)

CENTRAL TENDENCY

The degree of sameness is usually referred to as central tendencies and are identified as the "mean", "mode" and "median". For a group of data , mean is the same as average, median is the middle score, and mode is the score that occurs most often.

The purpose of these measures of central tendency is to represent a group of data with one value that is a "summary" of the data in that group. The mean is generally the best representative of the combined contributions of an entire group of data and therefore is more frequently used in research.

However, it must be kept in mind that the mean acts only as a representative of the other data. A

simple example can illustrate how biased a mean may be:

A group of parents at a PTA meeting have a mean salary of $200,000 dollars per year. One of the parents is a millionaire.

The above mean salary is not representative of the ten salaries, and is misleading. The mean is most accurate as a representative of a set of data that is "evenly" or "symetrically" distributed.

The mean is so well known that it is not unusual for it to be referred to as the "average" or the "arithmetic mean", and many students are aware of no other measure of central tendency. Most people understand average as "THE SUM OF ALL VALUES (x) IN A SET OF DATA, DIVIDED BY THE NUMBER (n) OF VALUES.

The below examples illustrates the calculation of an average using the data from Table III on page 16.

CALCULATING MEAN

SEEDS EXPOSED TO 6000 A LIGHT

Mean = Sum of (x) / n

$$= \frac{.31+.24+.29+.24+.34+.24+.24+.30+.28+.22}{10}$$

= .27

SEEDS EXPOSED TO 4000A LIGHT

Mean = Sum of (x) / n

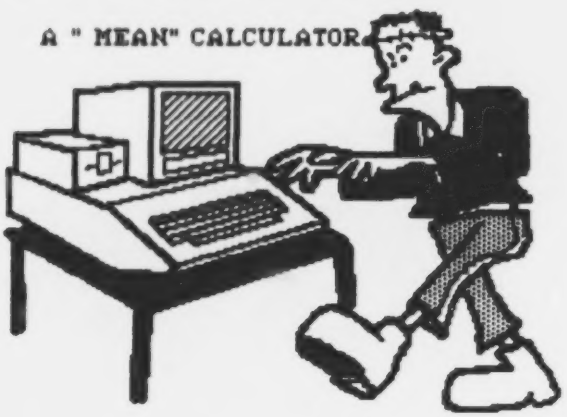
$$= \frac{.21+.20+.21+.22+.25+.24+.22+.21+.25+.19}{10}$$

= .22

If the two means are compared, it is obvious that there is a difference of 0.05 in the average respiration rates. Whether this is significant and how much dispersion is contained in the values will be discussed below.

A more detailed explanation of central tendency, how to calculate mode and median, and the usefulness of this type analysis can be found in a book on statistical analysis.

A " MEAN" CALCULATOR.



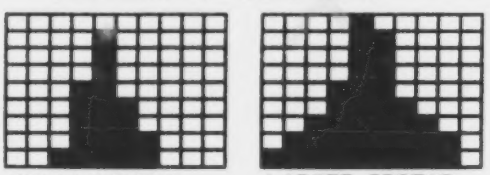
DISPERSION

The spread (dispersion) of a set of values is an important measurement to accompany the mean of those values. Two of the most commonly used measures are the range and standard deviation. The range is simply the difference between the highest value and the lowest value in a set of values. The standard deviation is a little more abstract but can be easily understood with a simple example.

If the mean age of all the students in a freshman class is calculated and then the ages sorted by age on a sheet of graph paper, it becomes obvious that the values "closely bunch up about the mean", indicating little dispersion . If you had to guess the age of a student from this freshman class, your best bet would be the mean.

If on the otherhand the mean age of all the students in this same high school is calculated, and then sorted as above, it is clear that the ages are widely scattered. The mean is now less useful, in predicting the age of an individual student from the school. The dispersion is greater. In general, the less dispersion, the more accurate will be guesses about individual values. (SEE CHARTS BELOW)

COMPARISON OF DISPERSIONS



SMALL SPREAD LARGER SPREAD

The preceding example indicates that the dispersion of a set of data should be measured in terms of the amounts by which the values deviate from their mean. Standard deviation can be thought of as an indication of the "average" of individual differences from the mean value of a set of data. The standard deviation has proved itself to be the best measure of this dispersion around the mean. It can be calculated in four easy steps.

CALCULATING S. DEVIATION

1. SUBTRACT EACH VALUE IN A SET OF VALUES FROM THE MEAN. THESE DIFFERENCES ARE CALLED DEVIATIONS.

2. SQUARE THE DEVIATIONS.

3. DIVIDE THE SUM OF THE SQUARED DEVIATIONS BY N-1.

4. TAKE THE SQUARE ROOT .

An example follows on the next page.

EXAMPLE OF CALCULATING STANDARD DEVIATION

6000A EXP. SEEDS

STEP 1 (M - x)	STEP 2 $(M-x)^2$
-.04	.0016
.03	.0009
-.02	.0004
.03	.0009
-.07	.0049
.03	.0009
.03	.0009
-.03	.0009
-.01	.0009

[STEP 3 -]

Mean of STEP 2 = Sum of STEP 2 / Number of values = .014/9 = .0016

[STEP 4 -]

STD.DEV.= STEP 4 = $\sqrt{.0016}$ = .040

Table IV shows a summary of the standard deviations and means for the two sets of respiration rates we have been considering.

TABLE IV

SUMMARY OF DATA FROM RESEARCH ON THE RESPIRATION OF CORN DEEDS

EXPERIMENTAL GROUP	MEAN	STD.DEV.
6000A	.27	.037
4000A	.22	.020

```
10   HOME
20   VTAB 5
30   PRINT "STANDARD DEVIATION"
35   PRINT "& MEAN CALCULATOR"
80   FOR X = 1 TO 2000
90   NEXT X
100   HOME
110   VTAB 15
120   INPUT "HOW MANY VALUES";N
130   DIM A(N)
140 S = 0
150   PRINT : PRINT "ENTER VALUES"

160   PRINT "PRESS RETURN AFTER"
165   PRINT "EACH VALUE"
166   PRINT
170   FOR I = 1 TO N
180 :: INPUT A(I)
190 S = S + A(I)
200   NEXT I
220 M = S / N
230   PRINT "MEAN","STANDARD DEV."

240   PRINT : PRINT : PRINT M,
250 SS = 0
260   FOR I = 1 TO N
270 DF = A(I) - M
280 SS = SS + DF * DF
290   NEXT I
300 STDDEV =  SQR (SS / (N - 1))
310   HTAB 25
320   PRINT STDDEV
340   END
```

Table IV shows a summary of the standard deviations and means for the two sets of respiration rates we have been considering.

TABLE IV

SUMMARY OF DATA FROM RESEARCH ON THE RESPIRATION OF CORN DEEDS

EXPERIMENTAL GROUP	MEAN	STD.DEV.
6000A	.27	.037
4000A	.22	.020

SIGNIFICANCE OF RESULTS

Looking at TABLE IV it is obvious that there are differences between the respirations of the two groups of seeds. The question that must now be answered is, "Was this difference caused by chance or by the different wavelengths of light?"

As mentioned earlier, the standard deviation indicates the average deviation of the individual values from the mean. The significance of this average lies in the fact that, in practice, a certain percentage of values in a set of data can be found to occur within a set of limits given by - the Mean(M) (+ or -) some multiple of the standard deviation.

More specifically, for a "normal distribution" (See note below), certain percentages will fall within definite ranges, as follows:

68% within --> mean(+ or -) 1(std.dev.)

95% within --> mean(+ or -) 2(std.dev.)

99% within --> mean(+ or -) 3(std.dev.)

Table V below illustrates these ranges for the corn seed experiment.

NOTE - Even though the distribution of data is not "normal", these percentages may be approximately realized. No matter how a series is distributed, M(+or-)2SD will include 75% or more of the items. This can be shown using Tchebycheff's inequality.

TABLE V

STD.DEV.	RANGE IN ML'S OXYGEN/HR. 6000A	RANGE IN ML'S OXYGEN/HR. 4000A	% POP.
+/- (1)	.23 to .31	.22 to .24	68
+/- (2)	.20 to .34	.18 to .26	95
+/- (3)	.16 to .38	.16 to .28	99

The results in Table V indicates that the likelihood of a corn seed exposed to 4000A light and tested under the same conditions, having a respiration of less than .18 mls of oxygen/hour or greater than .26mls/hr is remote -less than 1 in 95.

However the seeds exposed to 6000Å light have respiration rates greater than 0.26 ml oxygen/hour. This means that these rates occurred by a chance of 1 in 95 if no other influences were involved. Not likely and we know that there is a different influence - the independent variable of 6000Å light.

Comparing the values from the 4000Å seeds to the ranges of the 6000Å seeds, shows that there is a 1 in 68 probability that the respiration rates less than 0.23 occurred by chance. Again we suspect that the difference was caused by the independent variable.

How can we confirm our suspicion that these differences in respiration rates are not chance occurrences. There are additional statistical tests that can be performed to decide.

STUDENT "t" TEST

To use the Student "t" test, the assumption must be made that there are no differences between the two experimental groups. This assumption is called the "null hypothesis" and is discussed very clearly on page 80 of " Biological Science - Interaction of Experiments and Ideas".

" The null hypothesis is not the investigator's experimental hypothesis, which usually assumes there will be a difference between experimental and control samples. The null hypothesis is used only in statistics to test two samples. If the difference is large enough to support the probability that it is not due to chance variation, we reject the null hypothesis."

The significance of the value of "t" is also discussed.

"Calculating the value of "t" will enable us to compare two population samples and to determine the probability of their representing a single or two different populations."

CALCULATING "t"

"t" can be calculated using the formula below, if the number of data points are the same in each set of data.

$$t = \frac{M_1 - M_2}{\sqrt{\frac{SD_1^2 + SD_2^2}{n}}}$$

Where - M1 is the mean of one set of values.

M2 is the mean of the second set.

SD1- the standard deviation of the first set.
SD2- the standard deviation of the second set.
n- the number of values in each set.

All of the statistical calculations mentioned in this section of the module can be greatly simplified and clarified using a well designed spreadsheet. Appendix D contains a printout of an "APPLEWORKS" spreadsheet designed to analyze two sets of data of 10 values each. A copy of the template for creating the spreadsheet is also given.

If you are not familiar with spreadsheets or you cannot complete any ot the calculations mentioned, see your teacher or consult a mathematics book. A list of recommended books are given at the end of this section.

DRAWING CONCLUSIONS

The "t" value for the corn seed research is -4.0. (See Appendix D) This indicates that their mean respiration are approximately 4 standard deviations apart. This is not likely to occur by chance. What is the probability that it is wrong to make this assumption ?

Once "t" is calculated, this probability can be looked up in a "t" Table of Probability. (See The Handbook of Mathematics and Physics, or a good book on statistics)

The actual probability of a certain value of "t" depends upon the number of data values; the "t" is said to have a certain number of "degrees of freedom", equal to (n-1), where (n) is the sample size. If there are two sets of data, the total degrees of freedom is calculated as follows:

d.f.(degs. of freedom = (n1 - 1) + (n2-1)

For the seed project, d.f. = 18.

Using this df and a "t" probability table, yields the "t" values below at certain probabilities.

PROBABILITY	"t"
0.1	1.7
0.05	2.1
0.01	2.9
0.001	3.9

The "t" value from the seed data is approximately that at the .001 probabilty level. This means that the null hypothesis, that there is no difference in the respiration rate of corn seeds exposed to 4000Å light and cornseeds exposed to 6000Å light, IS CORRECT ONLY 1 IN 1000 TIMES. Since all known variables were CONTROLLED, except the INDEPENDENT VARIABLE (the wavelength of light), we can confidently conclude that the values of the DEPENDENT VARIABLE (respiration rate) was caused by the variation in the lights wavelength. Being able to draw final conclusions about your research depends on this sort of analysis.

****** ASSIGNMENT VI ******

Using the data from your research, complete WORKSHEET VI. If you have trouble with the calculations, obtain some help. Check your results on a computer.

WATCH THAT DUE DATE !!!

WORKSHEET VI ------>> DATA ANALYSIS

Name

_____Class_____

I- If you are trying to determine the relationship between an Independent and Dependent variable, plot the variables according to the guidelines on page 18. Using a line of best fit computer program or comparing your graph to the common relationships on page 19, find the equation that best describes your data.

II- If you are comparing the results of two sets of data , complete the table below and do the calculations described on pages 20,21 and 22.

DATA EXPERIMENT £1				DATA EXPERIMENT £2			
N	X	X-M	$(X-M)^2$	N	X′	X′-M′	$(X'-M')^2$
1				1			
2				2			
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9				9			
10				10			
SUM							

CALCULATIONS RESULTS:

M_____ M′_____

SD_____ SD′_____

"t" _____

With what confidence can the "null hypothesis" be rejected ? _____.

What is the conclusion that can be drawn from this data ?

_____

STEP VII

WRITE FINAL PAPER

The primary goals of a scientific paper is both to have your readers understand you and to pursuade them that the conclusion(s) you have drawn from your research is correct. These goals can be accomplished if you write clearly, accurately and concisely.

A scientific paper usually contains nine distinct sections. These include:

I- Title page
II- Abstract
III- Introduction
IV- Method
V- Results
VI- Discussion & Conclusion
VII- Bibliography
VIII- Acknowledgements

The content and purpose of each of these sections is as follows -

I- TITLE PAGE

1. TITLE - A title should stand alone. It should concisely state the topic and clearly indentify the dependent and independent variables. (See page 14)

2. AUTHOR'S IDENTIFICATION - The students name, grade level, school, and school address should be included.

Below is a sample TITLE PAGE.

The Effects of 6000A And 4000A Light On The Respiration Rate Of Common Corn Seeds.

By

Joe Dokes

Riverside High School
Route 8
Greer, South Carolina
29651

II - ABSTRACT

The abstract could be the single most important paragraph in a scientific paper. It should be -

(1) ACCURATE - Identifies the dependent and independent variables and the research technique used. It never includes information not included in the body of the paper.

(2) BRIEF - The International Science And Engineering Fair abstract is 250 words or less.

(3) NONEVALUATIVE - Reports facts rather than drawing conclusions.

SAMPLE ABSTRACT

The below example uses the format recommended by the ISEF for preparing an abstract.

THE EFFECTS OF 6000A AND 4000A LIGHT ON THE GERMINATION OF CORN SEEDS
Joe Dokes, Riverside High , Route 8; Greer, S.C. 29651

The purpose of this project was to determine if the respiration rate of corn seeds is affected by 6000 angstrom and 4000 angstrom light.

The approach was to expose a group of seeds to 6000A light and another group to 4000A light for 24 hours, and then measure the rate oxygen is evolved for each group of seeds using a volumeter.

The two groups of respiration rates were compared using the "t" test and a statistical difference was found at p=.001.

COMPUTERIZE YOUR WRITING

If you have access to a computer, learn to use a word processor. Makes editing, rewrites, rough drafts, etc., a "COOL-BREEZE"

III - INTRODUCTION

The body of a scientific paper begins with the introduction, which should contain answers to four specific questions. If you have done a thorough job of completing Worksheets I thru VI, you already these answers.

The questions are given on the following page with a reference to the related worksheet and some additional hints. A good introduction will contain the answers to each question in a paragraph or two. It clearly describes how the work was done and what the results were.

III - INTRODUCTION Continued -

QUESTION 1. What was the source of the reseach topic ?
ANSWER- See Worksheet I & II
HINTS - Begin by orienting a reader to the overall problem by placing it in the proper historical perspective.

QUESTION 2. What other research has been done in this area and how is it relevant to your research?
ANSWER - See Worksheet II
HINTS - Reference to the research of other scientist to the study of your topic should be brief, citing only the research that specifically relates to your project.

QUESTION 3. In general terms, why was your research done?
ANSWER- Worksheet I, II, & III
HINTS - State clearly and concisely why the research was done. Give the implications of the study and state what theory is being tested.

QUESTION 4. What is the precise purpose of the research ?
ANSWER - Worksheet III
HINTS - Should define the dependent and independent variables. Should begin - "The purpose of this project was to _____. (SEE PAGE 8)

The objective of the introduction is to make the paper self-contained for a reader knowledgeable about the field of interest, but not the specific problem. A good introduction will show a considerable understanding of what research has been done leading directly to the problem you have undertaken.

Convince the reader that your research was of sufficient interest to have done it.

IV METHOD

The METHODS section should be broken down into three subsections. Examples of these for the seeds respiration project are given.

1. TEST SUBJECT IDENTIFICATION - "Butterfruit" sweet corn seeds. Obtained from Parks Brothers seeds. Taken from 1985 harvest.

2. APPARATUS - (See pages 14 thru 16 and Worksheet V) The following apparatus was used to control and/or measure the variables indicated.

DEPENDENT - Respiration rate - A Bobbitt Laboratories volumeter and a Zollinhofer manometer.
INDEPENDENT - Wavelength of light - Filters - CBS Blue 450 and CBS Red 650
CONTROLLED - Temperature - Thermometer; Moisture - all seeds soaked for same length of time.

3. PROCEDURE - A summary of each step followed in completing the experimental phase of the project. Most of this should have already been done when completing Worksheets IV & V. (Pages 10 thru 17). It should tell what you did and how!

V - RESULTS

This section is strictly a presentation of the data gathered during the experimentation. The data should be in table form (See page 16, Table II) . Be sure to give units for all numbers. Use graphs where appropriate. (See Step Six). Make sure they are completely and clearly labeled, scaled and given units.

Statistical analysis data should include the value of the test, the probability level and the degrees of freedom. Be sure to include the mean and standard deviation. Doubts about the suitability of a test should be justified.

VI- CONCLUSIONS

This section explains how you interpreted the above results. What do they mean? What conclusions can you draw as a result of the research you have done? Reference should be made to the purpose formulated in Step III on page 8.

Point out similarities and differences between your findings and the work of others to clarify your conclusions, if needed.

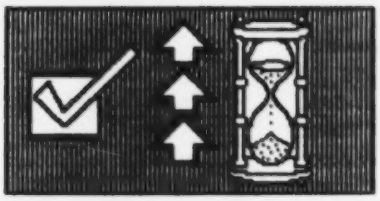
You should answer the following questions - (1) Has my research resolved my original "Cause - Effect" question? (2) What implications can I deduce from my research ?

VII -BIBLIOGRAPHY

The bibliography is a list of specifically pertinent resource materials. On the following page of "HINTS FOR WRITING AN AWARD WINNING PAPER" is an example of a bibliography format.

VIII - ACKNOWLEDGEMENTS

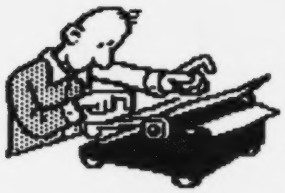
This section gives the names of all the folks who helped you complete your paper. Include teachers, parents, other students, and friends.



At this point you should have completed the following-

- [ ] Filled in due date on "Check List"
- [ ] Selected A Topic "Worksheet I"
- [ ] Know Your Topic "Worksheet II"
- [ ] Have A Purpose "Worksheet III"
- [ ] Plan Your Project "Worksheet IV"
- [ ] Start Experiments "Worksheet V"
- [ ] Data Analysis "Worksheet VI"

HINTS FOR WRITING AN AWARD WINNING SCIENCE RESEARCH PAPER



Put pages in this order.
(1) Title page
(2) Abstract
(3) Introduction
(4) Method
(5) Data
(6) Conclusions
(7) Bibilography
(8) Acknowledgement

TYPING GUIDE

MARGINS - Left: one and one-half inches
Right: one inch
Top: one inch; Bottom: one inch
NUMBERING - The introduction is page one. All subsequent pages are numbered consecutively.
TYPING - (1) TITLE PAGE - See example on page 24.
(2) ABSTRACT - Single spaced, following example on page 24.
(3) INTRODUCTION - The word INTRODUCTION is to be centered and typed in all-caps on the twelfth line. After triple spacing, begin typing the introductory comments. (Double spaced)

*** NOTE - The above mentioned rules are only "rule of thumb". Follow the style guide suggested by your teacher.

The following is an excellent guide for correctly writing research papers.

"PUBLICATION MANUAL OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION":Washington, D.C.; American Psychological Association, 1200 - 17th Street; 1983

EXAMPLES OF BIBLIOGRAPHY FORMAT

BOOKS -
DeJong, Marvin L. "Apple II Applications", Indiana: Howard W. Sams & Co., Inc. 1983

ARTICLES-
Magazine Article:
Rowson, David J. " Competing" 'The Science Teacher',22 (December 1985) :32.

Newspaper Article:
Edson, Lee. "Enzyme Explosion." 'New York Times' Nov.7,1979

Encyclopedia
"Epistrophe," 'Webster's New International Dictionary'. 2D ed., 1982

See a style guide for other publications.

WARNING!

The directions given in Step VII of this module may be hazardous to the success of your project in a particular competition. It is your responsibility to obtain the specific guidelines for preparing your paper for a particular science fair or paper symposium. Check with your teacher, and/or write to the director of a particular competition for specific details. (See Step IX for addresses)

ADDITIONAL TIPS TO KEEP IN MIND

(1) ALWAYS CONVEY AN OBJECTIVE IN CALM TONE IN YOUR REPORT. THERE SHOULD BE AN ABSENCE OF EMOTION.
(2) THE SCIENTIFIC POINT OF VIEW IS IMPERSONAL. OMIT ELEMENTS WHICH ARE PERSONAL. THE ACTIVE VOICE AND FIRST PERSON (I, ME, MINE: "I MIXED THE SOLUTION") IS NOT ALLOWED. IT SHOULD BE : " THE SOLUTION WAS MIXED..." (PASSIVE VOICE)

MISUSED WORDS

AFFECT-EFFECT - "Affect" is commonly used as a verb that means to influence; "Effect" is commonly used as a noun that means the result or outcome.

CONSENSUS - It is redundant to write - "consensus of opinion"

REVERT BACK - Another redundancy. Simply use revert.

THUS-THUSLY - "Thus" is an adverb by itself and needs no suffix.

REASON IS BECAUSE - Still another redundancy. "Because" means "for that reason."

IMPLY-INFER - The author implies, the reader infers.

**** ASSIGNMENTS VII -WRITE PAPER ****

COMPLETE WORKSHEET VII AND HAND IN BEFORE THE DUE DATE. YOUR TEACHER WILL ALSO GIVE YOU A DATE THAT A ROUGH DRAFT OF YOUR PAPER IS DUE. ASK FOR THIS DATE AND SPECIFIC DETAILS ON WRITING YOUR PAPER.

WRITE YOUR REPORT ----- > > WORKSHEET VII

NAME_____CLASS_____

PROJECT TITLE _____DATE _____

A rough draft of your report is due on _____. You should use the guidelines on pages 24 thru 26 in preparing this draft. As you proceed, use the below checklist. Attach this sheet to your rough draft.

I - TITLE PAGE

[ ] Title contains dependent and independent variables.
[ ] Identification information is given.

II - ABSTRACT

[ ] Begins with a statement of pupose. (See Worksheet III)
[ ] Written in third person, past tense.
[ ] Length less than 250 words.
[ ] Includes brief statement on the results.
[ ] Contains brief, general statement on how research was done.

III - INTRODUCTION

[ ] Describes source of research idea.
[ ] Describes other relevant research on your topic.
[ ] Answers question - "Why was research done?"
[ ] Gives precise purpose of research.

IV - METHOD

[ ] Identifies test subjects.
[ ] Describes apparatus used to control variables.
[ ] Gives concise description of experimental method.

V - RESULTS

[ ] Data are given in table or graphic form.
[ ] If a calculation was required, it is described.

VI - CONCLUSIONS

[ ] Includes interpretation of results.
[ ] Refers to original purpose. (See Step III, page 8)
[ ] States the relationship between the dependent and independent variables.
[ ] Gives implications of results.

VII - BIBLOGRAPHY

[ ] List specifically pertinent resources.

VIII - ACKNOWLEDGEMENTS

Now that your research and paper are finished, it is time to share your findings with the public. As a high school student you have the opportunity to report your study in three ways:

* SUBMIT A WRITTEN COPY OF YOUR PAPER FOR JUDGING.

* PREPARE A SCIENCE FAIR EXHIBIT DISPLAYING YOUR RESULTS.

* GIVE AN ORAL PRESENTATION OF YOUR RESULTS.

The previous step in this module explained how to prepare a written paper. This step explains how to construct an exhibit and how to prepare and give an oral report.

The last step, Step Nine, discusses in detail the specifics of where, when, and how to enter your exhibit and paper in local, state, and national competitions.

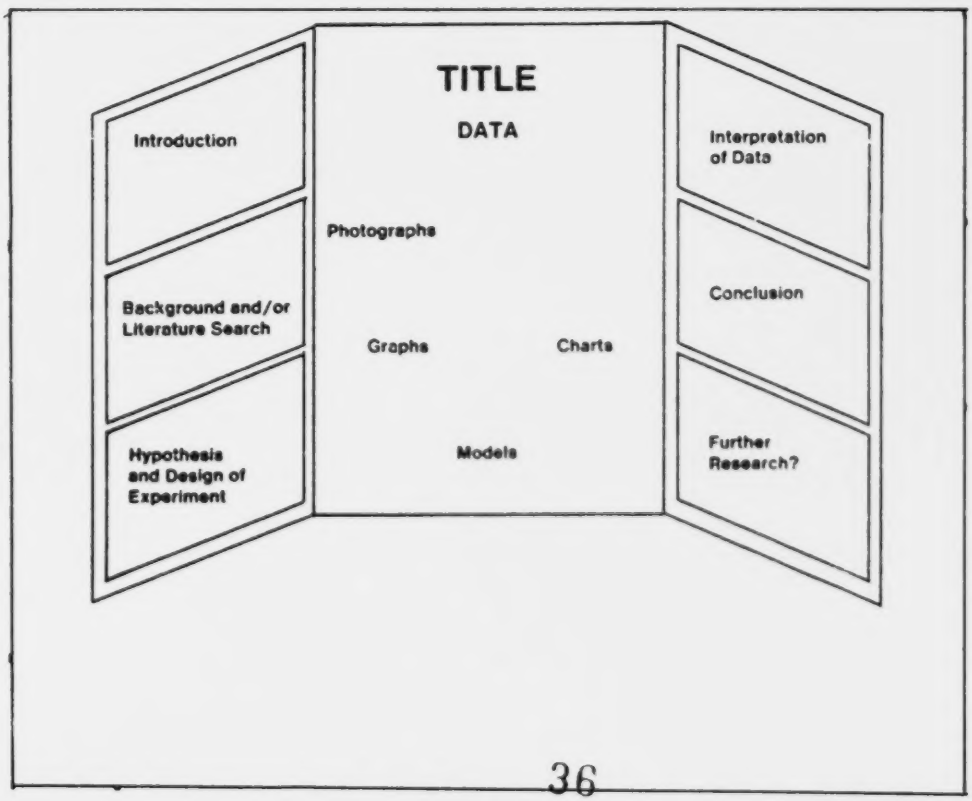
SCIENCE FAIR EXHIBITS

Any good scientist would agree that constructing a science fair exhibit is not true science or engineering. However, they would also agree that in order to pursuade society that the conclusions drawn from your research is valid, the manner in which you present your results is of major importance. The sketch below is a typical science fair backboard. The display describes, in a summary format, the entire project - from the initial proposed purpose, through experimentation, to conclusions.

The key to an effective backboard is planning. Review in your mind your research and plan your exhibit to highlight the story you want to tell. This planning is simpler if done in steps.

BUILDING THE BACKBOARD

The style backboard below is the most typical. It can be one large board held up like a table picture frame, a self supporting booth, or an aluminum frame with fabric stretched over it. You are encouraged to use



your own creative ability in designing your backboard. According to International Science and Engineering Science Fair standards, a project is limited to 274 cm (9 feet high, floor to top), 122 cm wide (48 inches wide, side to side) and 76 cm deep (30 inches deep, front to back). It can be smaller, but will be disqualified if its larger.

The backboard on the previous page can be constructed from a 4ft x 8ft sheet of the materials listed in the below table. The center board is 4ft x 3ft. Each side panel is 4ft x 30 inches. (See Cutting Diagram) Hinges are used to attach the side panels to the center panel. If this tri-fold backboard sits on a 3ft high table, it will meet the limitations set by the International Science Fair Committee.

BUILDING MATERIALS

MATERIAL	SOURCE	HINGES
1/4" Plywood	Building supplier	Hinges
Peg Board	"	"
Hard Board	"	"
Styrofoam	"	Duct Tape
Foam - Core	Art supplier	"
Mat Board	"	"
Cutting Board	Sewing Store	"
Cardboard	Old Refrig. Boxes	"

CUTTING DIAGRAM

COVERING THE BACKBOARD

The materials above, with the exception of styrofoam, can be painted. (Use water base paint). They can also be covered with, colored burlap, colored paper, wall paper, etc. USE YOUR IMAGINATION!

LETTERING THE BOARD

There are a wide variety of ways that you can label the different sections of your backboard. Avoid hand lettering unless you are a good artist. Use stencils or commercially available "Peel off - Stick on letters".

The newest, method is to use a computer graphics program such as "Print Shop" or "Newsroom" to prepare titles and labels. These techniques produce professional looking boards.

COMPLETING THE BOARD

CHARTS, GRAPHS, & TEXT - All text should be typed, never handwritten. Sheets of text should be backed with sheets of colored construction paper. Chose a color that complements your backboard. Attach sheets to the backboard with staples or tape. Never glue them to the board.

PHOTOGRAPHS - Use photographs. "A picture is worth a thousand words." Back all photos with construction paper. If they trace a sequence of events, place the photo of the earliest event on the left. For other themes, place the most attention - getting picture in the center, then arrange the less spectacular pictures around it.

SPECIMENS - If your project has a number specimens , small models or other three-dimensional objects, they can be displayed on small shelves attached directly to your backboard.

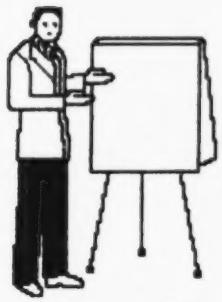
Do not exhibit live or preserved vertebrate animals. Do not exhibit live invertebrates, either. Use photographs, slides, video tapes, or sketches to report results of vertebrate research.

! ! SAFETY!!

The following list of precautions should start you thinking about safety in doing your research and exhibiting your results. Your exhibit must comply with these and all other regulations required by your science fair. The following may not be part of your project.

PROHIBITED

1. Flammable, corrosive , explosive or highly poisonous substances.
2. Aerosol cans.
3. Live animals of any kind.
4. Pathogenic cultures.
5. Hypodermic syringes or needles.
6. Only approved lasers.
7. Radiation hazards from an electrical apparatus or radioactive materials.
8. Armed rockets or propellants.
9. Electrical Hazards. Check with your fair director.
10. Unprotected moving gears, pulleys, etc.
11. Open flames.
12. Glass containers if plastic can be substituted.
13. Unstable backboards that may topple over.



ORAL PRESENTATION

Most oral presentations are given before a group of 3 or 4 judges and a group of participating students. You are usually given 10 to 12 minutes for the actual presentation, followed by a 3 to 5 minute question and answer session.

The success of your presentation will depend on your following a few simple tips and guidelines.

V I S U A L S

The main purpose of a visual is to promote understanding. If there is one simple rule to remember about using visuals it is -- USE ONE SIMPLE VISUAL TO EXPRESS A SINGLE IDEA. Don't clutter them up with too much material.

BLACKBOARDS

A blackboard is a handy visual device. It is big, simple, easy to use and usually available. Changes can easily be made and it doesn't have a bulb to burn out. Its best to have the information, sketches, etc., you are planning to put on the board on index cards in front of you. If you have never used a blackboard, practice using one before your presentation.

Colored chalk is most effective.

EASEL CHARTS

There are two types of easel charts - stiff individual cards and the "flip" type sheets. (See graphic that introduced this section)

The advantage of these type visuals is that they can be neatly prepared in advance. If your art abililty is limited, use stick on letters, a computer, or an artistic friend to help you.

Remember - ONE VISUAL PER IDEA BEING COMMUNICATED.

35MM SLIDES

Requires the most preparation if done correctly, but are very impressive. With the new polaroid 35mm film you can see your slides immediately and donot have to wait to see if remakes are necessary. Make sure each slide is clear and in focus.

Usually a carousel 35mm projector will be provided at the presentation site. Purchase or borrow a carousel and arrange the slides in it in the order you plan to use them. Make sure they are not in upside down or reversed. If the projector doesn't have a remote changer, have a classmate advance the slides for you. Clearly label the subject matter in each slide if possible.

OVERHEADS

This visual is the one most used by students. Personally, I like it best. The charts, graphs, text, etc., can be taken directly from your paper and converted to an overhead transparency. You can control the presentation of the material and not have to depend on an assistant.

The greatest advantage is the ability to "point" directly to the section of the visual which you are emphasizing.

Check at your office supply store for colored overhead sheets.

SPEAKING SUCCESSFULLY

To make a successful oral presentation you must learn some of the tricks of public speaking. Below is listed a few of the more important ones. Obtain a book on public speaking from your school library.

- UNDERSTAND YOUR RESEARCH COMPLETELY.
- ORGANIZE YOUR PRESENTATION.
- USE AN APPROPRIATE VOCABULARY.
- KEEP IT SIMPLE & CONCISE.
- LOOK NEAT & PROFESSIONAL.
- STANDUP STRAIGHT.
- NEVER READ A PRESENTATION.
- NEVER CHEW GUM.
- EXHIBIT ENTHUSIAM.
- MAKE EYE CONTACT.
- BE POLITE.
- IF YOU DON'T KNOW, SAY SO !
- BE POLITE.
- SPEAK CLEARLY.
- INTRODUCE YOURSELF.

****** ASSIGNMENT VIII ******

Once your backboard is finished, evaluate it by completing Worksheet # VIII. Turn this in to your teacher before the due date.

" Science is a collection of facts concerning natural objects or phenomena, arranged in good order, and made useful."

William T. Hornsday

WORKSHEET VIII ----- > > PREPARE EXHIBIT

NAME

_____

TITLE OF
EXHIBIT_____

I- Stand back, look at your exhibit, and check it against the following list. Have you:

[ ] talked to other students who have done projects?
[ ] looked at pictures and slides of awarding winning backboards?
[ ] designed exhibit on paper before constructing it?
[ ] kept it simple?
[ ] descriptions are brief and headlines tell the story?
[ ] used durable , safe materials?
[ ] chose colors carefully?
[ ] practiced neatness?
[ ] exhibit is portable and easy to erect?
[ ] used prepunched letters or computer to prepare titles?
[ ] the exhibit tells the story of what you did and what you concluded?
[ ] meets specifications of science fair?

II - On a sheet of paper, make a sketch of your backboard. Indicate colors, lettering, titles, etc.

TEACHER COMMENTS

I have checked your backboard and found:

[ ] It needs further work on the following.

[ ] TERRIFIC AS IS! GOOD WORK AND GOOD LUCK !!

Teacher_____Date_____

PRESENTING AN AWARD WINNING SCIENCE RESEARCH PAPER

BACKBOARDS

1. On the table in front of the display backboard, you can place equipment that you used or samples of your experimental group and control group. The backboard, your paper, and equipment comprise your exhibit.

2. Graphs, maps, cartoons, charts and pictures add variety to your display.

3. Color is better than black and white. This is true for pictures, titles, labels, printed messages, etc.

4. You only get one chance at the judges, so you have to catch their eye.

5. Plan your layout. Trim all materials and make your work as neat as possible. Lay out your backboard material on the floor before mounting. Try a few different arrangements. Be creative.

6. Discuss artistic details with your art teacher.

7. Attach pictures, etc. with transparent tape. Looks better than staples.

8. Never glue materials on the backboard.

9. Use rubber cement to attach material to construction paper mats. It does not leave wrinkles when it dries.

10. Have extra copies of your abstract available to give to judges and interested students.

11. Construct your own exhibit. Parents and teachers can only provide encouragement and constructive criticism.

12. Give your project a title that is captivating, prominently displayed and brief - no more than 45 characters and spaces allowed.

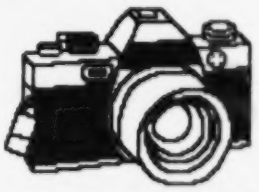
13. Keep your project within the ISEF space limitations. (76cmx122cmx274cm) Use photographs to show parts of your project that requires to much space.

14. Keep easels or tripods off the floor. Wall space cannot be used for display, or nearby drapes. Exhibits should be free standing and able to be displayed on the table space provided.

15. Remember - you are an important part of your project and exhibit. Your familarity with your research, general science knowledge, and personal appearance are important.

16. You must provide all materials required to assemble your exhibit. This includes extension cords, tape, tacks, staples, etc.

17. Have a copy of all certification sheets visible.



VISUAL AIDS

1. Keep the material simple and straight forward.

2. Never have more than eight lines of text on a visual.

3. Use key words and not sentences.

4. One visual per idea.

5. Use a minimum number of curves on a graph.

6. A visual should show:
   - How a thing looks.
   - How things are related.
   - How a think works.

7. If you are using a projector of any type, be sure:
   - Its available and set up before your presentation.
   - Its operational.
   - You have your slides of overheads.
   - Its focused.
   - You have a spare bulb.
   - You know how to operate it.

SPEAKING

REHEARSE IN FRONT OF A GROUP. REHEARSE IN FRONT OF A TAPE RECORDER. REHEARSE ! REHEARSE !

There are four basic types of science research competitions available to high school students. These are:

* A written paper
* An oral presentation
* A science fair exhibit
* An essay contest

These competitions exist on a local, state, national and international level. Which of are available on a local and state level depends on the school you attend, and the city and state in which you live. To follow are a series of "GUIDES" describing which competitions are available, the general requirements to enter, and an overview of the competitions in South Carolina.

>> G U I D E A <<

COMPETITIVE SCIENCE EVENTS IN S.C.	
LOCAL EVENT	REQUIREMENTS
School Competition	Depends
Regional Science Fair	Exhibit & Paper
Jr. Academy Chapter	Papers (W & O)
STATE	
S.C. Jr. Academy	Papers (W & O)
NATIONAL & INTERNAT.	
Westinghouse	Written Paper
AAAS	Paper & Exhibit
Edison & McGraw	Essay
Science Essay	Essay
Duracell	Written Paper
ISEF (International)	Exhibit & Paper

>> G U I D E B <<

REQUIREMENTS

WRITTEN PAPERS - Requires:

a. Conducting research.
b. Writing a report and summary of the project.

No exhibit is required !

ORAL PRESENTATIONS - Requires:

a. Conducting research.
b. Preparing and presenting an oral report of the project.

No exhibit or written paper is required. Visuals must be prepared.

SCIENCE FAIR EXHIBIT - Requires:

a. Conducting research.
b. Writing a report on the research.
c. Constructing and displaying a backboard.
d. Answering questions from a panel of judges.

This competition is the most comprehensive of those mentioned.

ESSAY CONTEST - Requires:

a. Conducting library research.
b. Writing an essay of a specific length.

A particular topic is designated.

>> G U I D E C <<

WHO TO CONTACT

LOCAL - School Events

Usually the best person to contact about school competitions is the county or district science consultant. This person is most likely located in the school district's office. In Greenville County contact -

Mr Bill Whittaker
Science Consultant
Greenville County
School District
301 Camperdown Way
Greenville, S.C.
29602

Regional Science Fairs -

Contact your state science consultant for the names of the regional science fair directors.
In South Carolina contact the following:

GREENVILLE - Western South Carolina REGION I Science Fair, Dr. Gilbert Fairbanks, Dept. of Biology, Furman University, 29613, (803) 294-3247. Sponsored by Greenville Rotary Club and Roper Mountain Science Center.

COLUMBIA - Central South Carolina REGION II Science Fair, Dr. Joseph E. Johnson, College of Science and Mathematics, University of South Carolina, 29208, (803) 777-2502. Sponsored by "The State Newspaper"

SPARTANBURG - Piedmont REGION III Science Fair, Dr Jeanne Kowalczyk, Department of Biology, University of South Carolina, 29303, (803) 578-1800, ext. 2753. Sponsored by The University of South Carolina - Spartanburg.

FLORENCE - Sand Hills REGION IV Science Fair, Dr Larry J. McCumber and Dr Kenneth Williams, Dept. of Biology, Francis Marion College, 29501, (803) 661-1401. Sponsored by South Carolina Academy of Science.

Continued next page.

CHARLESTON - Low Country REGION V Science Fair, Dr William Kubinec, Mrs Elizabeth Martin, and Dr Doug Kennard, College of Charleston, 29424, (803) 793-5649/5516/5618. Sponsored by College of Charleston.

AUGUSTA - REGION IV Central Savannah River Area Science and Engineering Fair, Miss Karen McMahan, 1017 Stevers Creek D130, Augusta, Ga.,30907, (404) 860-8095. Sponsored by Central Savannah River Area Science and Engineering Fair

PORT ROYAL - Sea Island REGION VII Science Fair, Emmitt "Buf" Bufkin, Chairman, P. O. Box 618, Port Royal, South Carolina 29935, (803) 524-3600 Sponsored by - A host of parents, companies , civic clubs, etc.

STATE COMPETITIONS-

Science Fairs- Contact your state science consultant. In South Carolina contact:

Mrs Peggy Cain
State Science Consultant
State Department of Education
801 Rutledge Building
Columbia, S.C. 29201

South Carolina Jr. Academy of Science - Contact a local college science professor. Ask this person if a junior academy exist, and if so who directs it. In S.C. contact:

Mr Bill Surver, Director
S.C. Jr. Academy of Science
Biology Dept., Clemson Univ.
Clemson, S.C. 29631

NATIONAL COMPETITIONS - Write to the following for:

Westinghouse Science Talent Search -

Dorothy Schriver, Director
Westinghouse Talent Search
Science Service
1719 N. Street, N.W.
Washington, D.C. 20036

American Junior Academy of Science-

Peggy Cain
State Science Consultant
State Dept. Of Education
801 Rutledge Bld
Columbia, S.C. 29201
803-758-2652

Duracell Scholarship Competition-

Duracell U.S.A.
Berkshire Industrial Park
Bethel, CT. 06801

Science Essay Awards Program-

1987 Science Essay Awards
c/o General Learning Corp.
3500 Western Avenue
Highland Park, Ill. 60035

Edison/McGraw Scholarship Program-

Mr Robert A. Dean
P.O. Box 80953
San Diego, Ca.
92138

Junior Science & Humanities Symposium -

Ms Barbara Osborne
Academy of Applied Science
Jr. Science & Humanities Sym.
4603 Western Blv.
Raleigh, N. C. 27606

National Science Olympiad

Mr Gerald Putz
5955 Line Pine Lane
Rochester, MI 48064

International Science & Engineering Fair - Contact Region director or

Science Service, Inc.
1719 N. St., N.W.
Washington, D.C. 20036

>> G U I D E D <<

RULES, REGULATIONS, AND GUIDELINES

School or District Competitions

A school or district science competition is an opportunity for students to practice preparing and presenting their research findings. It is therefore very important that the standards used at local competitions be the same as those used regionally, nationally and internationally. Some of these are discussed below and others can be obtained from the addresses given in GUIDE C.

Regional And International Fairs

Obtain copies of science fair rules and regulations from your regional director and write to ISEF for a copy of international rules.

A copy of the general rules, judging criteria and required applications for the Region I fair in South Carolina are contained in APPENDICES B, E, and F. APPENDIX G is a list of helpful publications available from the International Science and Engineering Fair.

The S. C. Jr. Academy of Science

The following are excerpts from "The South Carolina Junior Academy of Science Handbook."

III. How to Affiliate Your Club

Your present club can join the Junior Academy by sending the name of your high school, its address and phone number, the name, address, and phone number of your sponsor with dues to : (SEE GUIDE C FOR CURRENT DIRECTORS ADDRESS.)

IV. Junior Academy Functions

Each year academy members have an opportunity to participate in two workshops. While at these workshops, the students attend talks by interesting speakers, take tours of local industries, etc. Each workshop is a new and exciting experience. There is a fall workshop in early October and a winter workshop in late January. (Continued next page)

S.C.J.A.S. Continued -

These workshops are hosted by different Junior Academy chapters throughout the state.

In late March the Junior Academy holds its Annual Meeting in conjunction with the South Carolina Academy of Science. At this meeting, students present their individual research and compete for awards. Elections are also held to choose directors for the next year.

V. Deadlines

In order to present a paper at the annual meeting the student must submit an abstract to the Secretary around the end of January. The exact date varies from year to year and will be announced each fall in the November issue of the newsletter.

It is required that the student, also, submit a copy of his extended abstract to the Secretary around the middle of February if he wishes to compete for an award in research. (Written paper competition) Students submitting only short abstracts will only be eligible for awards in presentation. (Oral presentation)

Westinghouse Talent Search

Forty-four years of success are behind Westinghouse's effort to identify the most creative future scientist. The programs alumni includes five Nobel prize winners.

Students must submit the results of independent research and resumes by December 15th each year. This year's awards will include $140,000 in scholarships and 40 all-expense-paid trips to Washington for the Science Talent Institute. Write Science Service.

Duracell Scholarship Competition

Duracell administers this competition in an excellent fashion from beginning to end. The guidelines are clear, concise , and unrestrictive.

This year's entries in the Fourth Annual Duracell $30,000 Scholarship Competition are due February 24,1986 and should be sent to Duracell. For an official entry package, write to Duracell.

International Sci. & Engineering Fair

This international event is held each May with 500 to 600 contestants from regional and state fairs throughout the United States and a number of foreign nations.

This science fair is both a competition and an educational experience. It is one of the few competitions in the world wher the judges (More than 550) outnumber the contestants. Finalists say that one of the most enjoyable aspects is the opportunity to be interviewed by scientists, engineers, doctors, and mathematicians who are judges.

Each Finalist (those who attend), receive a silver medal embossed with a gold emblem. (See APPENDIX J for a list of awards) Write Science Service.

When you begin completing applications to enter science fairs and symposiums, you will have to answer the question, "In what category would you like to compete." An incorrect answer to this could prove fatal to your competitive success. Since the judges are required to judge the content of each project based on the category it ie entered in, you could be seriously penalized if you're in the wrong category. APPENDIX H list the categories offered by ISEF.

Judging Criteria

APPENDIX I gives the criteria used to judge the International Science Fair. Check it out!

**** FINAL ASSIGNMENT # IX ****

COMPLETE ASSIGNMENT SHEET IX AND TURN IN BEFORE THE DUE DATE. THIS IS A FINAL CHECK.

Before you enter your science project in any competition, give a lot of thought to the fact that any award that you may or may not receive is not the most important part of the competition. The satisfaction of using the scientific method to resolve a problem should be your greatest reward. Learning to use this great tool early in life can enrich your understanding of the natural world and become a valuable aid in dealing with daily problems. In his "Zen and the Art of Motorcycle Maintenance", Robert Pirsig describes it this way, " When I think of formal scientific method, an image sometimes comes to mind of an enormous juggernaut, a huge bulldozer - slow, tedious, lumbering laborious, but invincible. It takes twice as long, five times as long, maybe a dozen times as long as informal mechanic's technique , but you know in the end you're going to get it. There's no fault-isolation problem in motorcycle maintenance can stand up to it. When you've hit a really big one, tried everything, racked your brains and nothing works, and you know that this time Nature has really decided to be difficult, you say, Okay, Nature, that's the end of the nice guy, and you crank up the formal scientific method ....." GOOD LUCK !

ASSIGNMENT SHEET IX -----> > ENTER SCIENCE COMPETITION

Name _____

Project Title _____

Name of Competition _____ Date _____

I- Below is a list of competition requirements. In column # 1 check the items necessary to enter the competition listed above. Check column # 2 when the requirement has been met.

# 1	# 2	
[ ]	[ ]	A general application blank
[ ]	[ ]	Certification to begin research
[ ]	[ ]	Vertebrate animal certification
[ ]	[ ]	Qualified scientist certification
[ ]	[ ]	Adult supervision certification
[ ]	[ ]	Multiple copies of research paper
[ ]	[ ]	Written paper competition application
[ ]	[ ]	Oral paper presentation application
[ ]	[ ]	Science exhibit safety clearance
[ ]	[ ]	Audio-visuals
[ ]	[ ]	Backboard exhibit specifications
[ ]	[ ]	Mulitiple copies of abstract
[ ]	[ ]	Electrical safety clearance form
[ ]	[ ]	Shipment of science exhibit
[ ]	[ ]	Out of state travel
[ ]	[ ]	Informed consent certification
[ ]	[ ]	State eligbility requirement
[ ]	[ ]	Written essay of certain length
[ ]	[ ]	Parental permission form

II- Final teacher evaluation.

_____

_____

_____

_____

_____

_____

S C I E N C E P R O J E C T I D E A S -

APPENDIX A

Compiled By - Mike Farmer

BIOLOGY

1. Calcium and Egg Shell Thickness
2. Enzymes - Nature's Catalyst *
3. A Laboratory on Chemotaxonomy-Distribution of Betalains *
4. A Laboratory Exercise to Assess Transpiration (Biology Teacher,April 1982)
5. Clinical Urinalysis ;Determination of p-Aminobenzoic Acid *(Chem Ed. April 1974)
6. Biotechnology (Carolina Tips, Nov.1,1982)
7. Separation of Paprika Pigments
8. The Many uses of Urinalysis (Chem 13, Jan. 1981)
9. Biochemical ID of Bacteria (Carolina Tips,August 1,1984)
10. Juglone - (Chem Ed.)
11. Microbial Oxidation of Alkenes *
12. Micropropagation of Tobacco (Carolina Tips, Sept.1984)
13. Enzymatic and Colorimetric Determination of Serum Cholesterol (J. of Chem Ed,Jan.1978)
14. Developing an Environmental Garden
15. The Windgradsky Column (Carolina Tips ,Sept., 1978)
16. A Study in Litter Rates
17. Catching and Studying Snow Flakes
18. Raising Grasshoppers(Carolina Tips, June 1,1984)
19. Polyunsaturation in Food Products (Chemistry, Nov. 1974)
20. Carrying Capacity of a Grey Squirrel (Biology Teacher, Sept.1979)
21. Influence Of Tobacco on Brine Shrimp (Biology Teacher, Feb. 1981)
22. The Greater Wax Moth (Carolina Tips, Jan. 1,1983)
23. Learning in the Sow Bug (Scientific American)
24. Hormonal Control of Vertebrate Adaptive Color Changes (American Biology Teacher, Jan.1980)
25. Estimating Concentrations of Air Pollutants (Chem. Feb. 1968)
26. Antibiotics and Disinfectants
27. The Chlorophylls (J. of Chem Ed.,Nov. 1975)
28. A Convenient Method for Detergent Analysis
29. Color from the Fields
30. The Carnivorous Fungi
31. Relating Gaseous Exchange with Varying Temperatures in Rana pip.*
32. Demonstrating Evolution Between Animals
33. Respiration-An Experiment
34. Demonstrating the Carrier Properties of Hemoglobin
35. A Look at Hydrolytic Metalloenzymes *
36. Soft Drinks as Source of Carbon Dioxide in Studying Excyatation of Coccidian Oocysts
37. Experimenting With Threshold Vision *
38. The Turbatrix t Test.(Vol. 47 Carolina Tips)
39. Percentage Water in Plants (Search for Solutions Notes 6)
40. Making a Vaccine
41. Absorption of C-14 in a Closed Terrium
42. Effects of X-rays on Seed Germination
43. Effects of Magnetic Field on Yeast
44. Heatless X-Rays
45. The Effects of Air Pollution on Drosophila
46. Effects of Aldehydes on Euglena (Chemistry, July-August 1973)

MATHEMATICS

1.Simulation and the Microcomputer
2.Determining the Most Efficient Route (IEEE Micro-April 1983)
3.Geomegy or Geolotry
4.Conic Sections and Limacons -an Interesting Connection
5.Circles,Polar Graphs and a Computer
6.Simulating Radioactive Decay with Dice
7.Matrices in Optics
8.The Monochord,Mathematics and Musical Scales (Mathematics Teacher-March,1982)

GEOLOGY

1. A New Concept in Metallic Crystal Structure
2. Demonstration of the Optical Properties of Diamonds
3. Separation of Strontium in Radioactive Dating of Rocks
4. Investigating Paleontogical Succession
5. Studying the Freezing and Growth of Ice
6. Malachite and Calcite (Chemistry, Dec. 1975)

PHYSICS

1. Studying the Laws of Light Absorption
2. Design and Construction of an Efficient Parachute.(Air & Space-March 1980)
3. The Boltzmann Distribution of Molecular Velocities(Chem 13-Jan.1980)
4. Measuring the Strength of a Magnet With a Laser.
5. Measuring Small Diameters with a Laser
6. Checking Gear Wobble with a Laser
7. Photoexperiment Experiments With Cadmium Sulphide Cells
8. Determining the Solar Constant with a Microcomputer
9. Construction and Evaluation of a Simple Temperature Sensor
10.Sound in a Tube (Physics Teacher - May 1973)
11.The Ghost Flute (Physics Teacher -Dec.1975)
12.Doppler Re-Examined using an Apple
13.An Inexpensive Refractometer.(July-August,Chemistry 1974)
14.Measuring Speed of Light for $2.00 (Physics Teacher-March 1980)
15.Remote Sensing with Balloons(The Physics Teacher- Oct. 1982)
16.An Experiment for Testing Eye Resolution(Science Teacher-Dec.1961)
17.Determining Large Radii with a He-Ne Laser
18.Coefficients of Friction of Plastic Film
19.Vapour Pressure (Chem 13 Feb. 1981)
20.Non-linear Properties of Gases and Music (J. Chem Ed. -August 1979)
21.From Bohr to Quantum Mechanics via a Vibrating String (Chemistry,March 1975)*
22.Camera Calculations(Mathematics Teacher-May 1981)
23.Construction and Use of A Blinky
24.Studying Sound in a Gas Filled Tube with an Apple.
25.Measuring the Thrust of A Model Rocket(Physics Teachers-Nov. 1974)
26.Measuring the Solar Constant with an Apple
27.Measuring the Sun's Temperature
28.Insulations and the Rate of Heat Tranfer
29.Solar Heating Systems
30.Studying Pendulum Motion on the Apple
31.The Evaluation of Solid Propellants
32.Evaluating A Simple Mini-Battery
33.Computer Controlled Robotics
34.Measuring The Constant of Restitution of Silly Putty
35.Construction And Evaluation of a Solid State Device

CHEMISTRY

(A) INSTRUMENT CONSTRUCTION AND USE

1.Polarimeter
2.Calorimeter
3.Ion-Selective Electrode
4.Colorimeter
5.Coulometer
6.Refractometer
7.Gas Chromatograph (Chem 13,Sept.1979; Scientific American & Chem.April 1965)
8.Polarograph (Chemistry,March 1970)
9.Boltzmann Distribution Simulator

(B) EXPERIMENTAL RESEARCH

10.Determining Rate Contants and Activation Energy
11.Determining the Enthalpy of Hydration of Salts with a Computer
12.The Kinetics of Evaporation(Chem Ed. Oct.1978; Physics Teacher,Oct.1978)
13.Bonds Angles in Hydrogen Chloride and Ammonia
14.Growing Unusual Metallic Crystals
15.Chemistry in Silica Gel
16.Diffusion Through Gel Media
17.Acid-Base Equilibria (Chem. June 1975)
18.Determination of a Solubility Product Constant (Chemistry, June 1973;JCST,Jan.1977)
19.Demonstrating Transport Reactions
20.Stoichiometric Relationships in Two Systems
21.A Study of Phase Separation (Carolina Chemtips, Fall 1984)
22.Determining pKa's for Substituted 2-Nitrophenols (Chemistry,May 1971)

23.Catalytic Hydrogenation (Chem.. Jan.1974)
24.Studying the Mercury II Nitrate-Potasssium Iodide System (Chem.Feb 1965)
25. Investigating the Emerson Effect (JCST,Nov.1977)
26. A DTA Study of the Potassium Chlorate-Manganese Oxide System (Chem Ed.May,1983)
27.Microbial Oxidation of Alkenes (Chem Ed. July 1975)
28.The Effect of Solvent on Reaction Rate (Ed. in Chem.,July 1985)
29. Testing Suntan Preparations (Lab Manuals)
30. Kinetics of Enzymes (Several articles)

(C) CHROMATOGRAPHY

31.Quantitative Thin Layer Chromatography
32.Detecting Inorganic Ions Using Paper Chromatography
33.TLC Separation of Drug Alkaloids
34.Quick Paper Chromatography of Amino Acids
35.Photochemistry and TLC
36.Fatty Acid Characterization Using TLC
37.Studying the Genetics of Fruit Flies Using Chromatograms
38.Synthesis of Aspartic Acid in a Prebiological Environment
39. Vitamin C- Rate of Decay (JCST Feb.1974)

APPENDIX B VERTEBRATE ANIMAL CERTIFICATION #2

MUST BE COMPLETED FOR ALL VERTEBRATE ANIMAL RESEARCH PRIOR TO THE RESEARCH

Student's name (type or print) _____

School _____

A. Genus, species and common name of animals to be used

_____

B. Number of animals to be used _____

C. Animals to be obtained from _____

D. Describe proposed animal care

* (1) cage size _____

number of animals per cage _____

(2) temperature range in degrees Celsius of room where animals are to be kept

_____

(3) frequency of feeding and water _____

(4) frequency of cleaning cage _____

(5) type of bedding to be used (do not use cedar chips or newspapers)

_____

(6) where will animals be housed? (Animals infected with pathogenic organisms should be housed in institutional settings.)

_____

** (7) method of sacrifice, disposition, or current status of animals upon termination of the research (must be specific)

_____

(8) who will perform sacrifice if needed? _____

E. Teacher-Supervisor Signature _____

* See Guide for the Care and Use of Laboratory Animals, DHHS Publication #(NIH) 85-23 Revised 1985, $2.25. Order from Superintendent of Documents, US Government Printing Office, Washington, DC 20402. Stock #017-040-00498-2.

** State method of sacrifice or disposition of animals upon termination of research. (Note: Sacrifice should be performed by the qualified scientist, the designated adult supervisor, or the animal care supervisor. The following methods are acceptable: administration of barbituric acid derivatives in concurrence with the provisions of applicable laws, inhalation of ether, induced hypoxia with carbon dioxide or nitrogen and cervical dislocation. The following methods are unacceptable: injection of air into the brain, injection of any product containing strychnine, curare, succinylcholine or other neuromuscular blocking agents.)

REPRINTED WITH PERMISSION OF - Science Sevice, Inc.; Washington, D.C.

APPENDIX C

NAME	PUBLISHER	COMPUTERS	GRADES*	PRICE
FORMULATING HYPOTHESE				
Chem Lab Simulations 2	High Technology Software Products 8200 N. Classen Blvd., Suite 104 P.O. Box 60406 Oklahoma City, OK 73146 (405) 848-0480	Apple II family	9-12	$100.00
Discover	Sunburst Communications Room CE 39 Washington Ave. Pleasantville, NY 10570-9971 (800) 431-1934; (914) 769-5030	Apple II family	6-12	$ 59.00
Gertrude's Secrets	Addison-Wesley Software Division Sand Hill Rd. Menlo Park, CA 94025 (415) 854-0300	Apple II family	K-4	$ 59.95
King's Rule	Sunburst Communications (see previous listing)	Apple II family, IBM PC and PCjr, TRS-80, Tandy 1000, Color Computer, and Commodore 64	4-10	$ 59.00
Moptown Hotel	Addison-Wesley (see previous listing)	Apple II family, Atari	3-5	$ 54.95
Safari Search	Sunburst Communications (see previous listing)	Apple II family	3-9	$ 59.00
Stockmarket Simulation	Random House 400 Hahn Road Westminster, MD 21157 (800) 638-6460, ext. 2293	Apple II family, TRS-80	6-12	$ 59.95
PROBEWARE (COLLECTING DATA WITH REAL -TIME GRAPHING)				
Bank Street Laboratory	Holt, Rinehart & Winston 383 Madison Ave. New York, NY 10017 (212) 872-2213	Apple II + or IIe	3-12	$412.25
Frequency Meter	Vernier Software 2920 S.W. 89th St. Portland, OR 97225 (503) 297-5317	Apple II family	9-12	$ 39.95
Science Toolkit	Broderbund 17 Paul Dr. San Rafael, CA 94903 (415) 479-1170	Apple II family	3-9	$ 59.95
Sonic Ranger	TERC 1696 Massachusetts Ave. Cambridge, MA 02138	Apple II family	6-12	$ 7.00
GRAPHING YOUR DATA				
Easy Graph	Grolier Electronic Publishing 95 Madison Ave., Suite 1100 New York, NY 10016 (800) 858-8858; (212) 696-9750	Apple II family, IBM PC and PCjr, Commodore 64 and 128	3-6	$ 49.95
Graphical Analysis II	Vernier Software (see previous listing)	Apple II family	9-12	$ 24.95
Graphing Equations	Sunburst Communications (see previous listing)	Apple II family	8-12	$ 59.00
Interpreting Graphs	Sunburst Communications (see previous listing)	Apple II family	6-10	$ 59.00
ANALYZING PROBABILITIES				
Heath Math Worlds: Data Analysis	Collamore Education Publishing (D.C. Heath) 125 Spring Street Lexington, MA 02173 (800) 428-8071; (617) 860-1328	Apple II family	6-9	$ 81.00
Heath Math Worlds: Sampling	Collamore Education Publishing (D.C. Heath) (see previous listing)	Apple II family	6-9	$ 81.00
Graphical Analysis	Digipac Microcomputer Software 907 River St. East Prince Albert Saskatoon, S6V 0B3, Canada (306) 764-1707	Apple II family	10-12	$ 29.95

REPRINTED WITH PERMISSION FROM CLASSROOM COMPUTER LEARNING, APRIL 1986

APPENDIX D

OXYGEN CONSUMPTION BY CORN SEEDS AT 6000A AND 4000A

	ML O2 / PER HOUR		DEVIATIONS		DEVIATIONS SQUARED	
SAMPLE	6000A	4000A	6000A	4000A	6000A	4000A
1	.31	.21	-.04	.01	.0016	.0001
2	.24	.2	.03	.02	.0009	.0004
3	.29	.21	-.02	.01	.0004	.0001
4	.24	.22	.03	.0000000	.0009	.0000000
5	.34	.25	-.07	-.03	.0049	.0009
6	.24	.24	.03	-.02	.0009	.0004
7	.24	.22	.03	.0000000	.0009	.0000000
8	.3	.21	-.03	.01	.0009	.0001
9	.28	.25	-.01	-.03	.0001	.0009
10	.22	.19	.05	.03	.0025	.0009
TOTAL--	2.7	2.2	.0000000	.0000000	.014	.0038

	MEAN	VAR.	STD.D	T VALUE
6000A ---	.27	.0016	.0394	3.555
4000A ---	.22	.0004	.0205	

OXYGEN CONSUMPTION BY CORN SEEDS AT 6000A AND 4000A

	ML O2 / PER HOUR		DEVIATIONS		DEVIATIONS SQUARED	
SAMPLE	6000A	4000A	6000A	4000A	6000A	4000A
1	.31	.21	+C22-C8	+C23-D8	+(E8*E8)	+(F8*F8)
+B8+1	.24	.2	+C22-C9	+C23-D9	+(E9*E9)	+(F9*F9)
+B9+1	.29	.21	+C22-C10	+C23-D10	+(E10*E10+(F10*F10	
+B10+1	.24	.22	+C22-C11	+C23-D11	+(E11*E11+(F11*F11	
+B11+1	.34	.25	+C22-C12	+C23-D12	+(E12*E12+(F12*F12	
+B12+1	.24	.24	+C22-C13	+C23-D13	+(E13*E13+(F13*F13	
+B13+1	.24	.22	+C22-C14	+C23-D14	+(E14*E14+(F14*F14	
+B14+1	.3	.21	+C22-C15	+C23-D15	+(E15*E15+(F15*F15	
+B15+1	.28	.25	+C22-C16	+C23-D16	+(E16*E16+(F16*F16	
+B16+1	.22	.19	+C22-C17	+C23-D17	+(E17*E17+(F17*F17	
TOTAL--	$SUM(C8..$SUM(D8..		$SUM(E8..$SUM(F8..		$SUM(G8..$SUM(H8..	

	MEAN	VAR.	STD.D	T VALUE
6000A ---+C19/10	+G19/9	$SQRT(D22		+(C22-C23
4000A ---+D19/10	+H19/9	$SQRT(D23		

APPENDIX E

LOCAL AND STATE REGULATIONS FOR SCIENCE FAIRS

Safety Rules

A. Anything which could be hazardous to public display is prohibited. This includes:
   1. Live posionous animals.
   2. Live disease-causing organisms which are pathogenic to man or other vertebrates.
   3. Any flames, open or concealed.
   4. Highly flammable display materials.
   5. Dangerous chemicals such as caustics and acids.
   6. Highly combustible solids, fluids, or gases, inert substances must be used if such materials are required for display.
   7. Tanks which have contained combustible gases, unless they have been purged with carbon dioxide.

B. Prior attention to safety is expected of all science fair participants, including compliance with the following requirements for all operating exhibits:
   1. Any project producing temperatures exceeding 100° C (212° F) must be adequately insulated from its surroundings.
   2. Batteries with open top cells are not permitted. Other types of batteries may be used for electric power.
   3. High voltage equipment must be shielded with a grounded metal box or cage to prevent accidental contact.
   4. Large vacuum tubes or dangerous ray-generating devices must be properly shielded.
   5. High voltage wiring, switches and metal parts must be located out of reach of observers and designed with an adequate overload safety factor.
   6. Electric circuits for 100-volt AC must have an Underwriters Laboratories approved cord of proper load-carrying capacity, which is at least six feet long and equipped with a standard plug.
   7. All wiring must be properly insulated. Nails, tacks, or uninsulated staples must not be used to fasten wiring.
   8. Bare wire and exposed knife switches may be used only on circuits of 12 volts or less; otherwise, standard enclosed switches are required.
   9. Electrical connections in 110 volt circuits must be soldered or fixed under approved connectors and connecting wires properly insulated.

Regulations for Experiments with Animals

The legitimate use of animals in the classroom, in the laboratory, or in science fair projects presupposes two postulates. First, the use of animals for learning, as it is for testing and research, is morally acceptable; and second, that man has a responsibility to grant the animals he uses for his benefit every humane consideration for their comfort and well being.

APPENDIX E

The moral responsibility that we all have toward animals means that we cannot give free rein to students in projects involving animals. Consequently, those of us who would nurture a healthy curiosity in youngsters are placed in a delicate position. To "turn off" a prospective biologist or physcian by excessive limitations would be a serious mistake. For we know that through science fair work, thousands of today's physicians, dentists, veterinarians, scientists, engineers, and science teachers were given important impetus toward their careers.

The proper care and use of animals is a prime concern that cannot be ignored. If the student can learn this concern, and if he can learn something about animals and their needs, it will be a valuable addition to him as a person and to his knowledge of biology.

Before proceeding with any phase of animal experimentation a teacher's certification must be completed to insure understanding and compliance with existing ISEF rules. (See page 33)

An animal care supervisor must be directly involved in every project, and primary responsibility for the animals must lie with this adult even though exceptional students may have developed the concern and knowledge necessary for the proper care and use of animals. A necessary part of some investigations may involve situations in which discomfort might be experienced by the experimental animals, but such experiments may only be undertaken when the learning experience justifies the procedure.

Regulations for Experiments with Live Vertebrate Animals

A. The basic aims of experiments involving animals are to achieve an understanding of the life processes and to further man's knowledge. All experiments involving live vertebrate animals (excluding home sapiens), vertebrate embryos and fetuses, and embryos of domesticated fowl within three days of hatching, must conform to the following rules:
   1. Teacher Certification (Certification #1)--(See page 33)
   2. Experiments must be conducted with a respect for life and an appreciation of humane considerations that must be afforded all animals. They do not include the development of new or refinement of existing surgical techniques.
   3. Animal Care Supervisor (Certificate #2)--(See page 33)
      The comfort of animals used in any experiment shall be of prime concern. No experiment using live animals shall be attempted unless the animals shall have been obtained from a reliable source and the following conditions can be assured: appropriate, comfortable quarters; adequate food and water; humane treatment and gentle handling. Proper quarters and care must be provided at all times, including weekends and vacation periods.
   4. Bimedical Scientist Certificate (Certificate 3a)--(See page 33)
   5. Protocol Considerations
      A protocol is defined as an orderly presentation of the proposed procedures which will be used during the experiment, including objectives of the experiment, description of the methods and techniques to be used, materials, animals to be used, site at which experiment will be performed, animal care, and disposition of animals.

A protocol describing the proposed investigation must be submitted by the student and approved in writing prior to the beginning of the investigation.

B. Criteria for Participation in Fairs
   1. All animal experimentation projects entered in an affiliated fair of the ISEF should be evaluated before final approval for exhibition by a local animal experimentation committee upon receipt of the abstract, the necessary certifications, protocol, and bibliography.
   2. Students whose exhibits are disqualified in an affiliated fair will not exhibit. Students whose exhibits are disqualified prior to the ISEF will not exhibit at the ISEF, and a substitute may be provided.
   3. The Animal Experimentation Committee will use the following criteria in evaluating the project, necessary certification, protocol, bibliography and exhibit:
      a. Educational value of the project for the student.
      b. Adequacy of literature search.
      c. Quality of care for and treatment of animals.
      d. Disposition of animals after project (including if euthanasia was necessary, by whom and how it was accomplished).
      e. Euthanasis should be performed by the qualified bio-medical scientist, the designated adult supervisor, or the animal care supervisor. The following methods are acceptable: administration of barbituric acid derivatives in conformance with provisions of applicable laws, inhalation of ether or chloroform, induced hypoxia with carbon dioxide or nitrogen, and cervical dislocation. The following methods are unacceptable: injection of air into the brain, injection of any product containing strychnine, curare, succinylocholine or other neuromuscular blocking agents.[5]

NON-ATHLETIC ACTIVITIES

Section 10: To be eligible to participate in the non-athletic activities of the League, a student must meet the following requirements:

A. A student becomes ineligible on his/her 19th birthday except that a student who becomes 19 after November 1 is eligible to compete in all non-athletic activities of that school year. Birth certificates are not required, but the principal will certify the age of each contestant.
B. A student must be a bona fide 7-12 grade student taking a minimum of three units of work, or their equivalent, for which no previous credit has been received.
C. A student will become ineligible at the end of the fourth school year from the date that he first entered the 9th grade.
D. To be eligible during the first semester, student must have passed three carnegie unit subjects or their equivalent the previous school year.
E. To be eligible during the second semester, student must have passed three carnegie unit subjects or their equivalent the first semester.
F. A student must meet all the attendance, residence, and transfer requirements of Article VIII.
G. Awards will be appropriate in number, and value. Scholarships are regarded as a desirable type of award for non-athletic events provided that they are paid directly to the institution selected by the student.[6]

FURMAN UNIVERSITY

FOUNDED 1826

GREENVILLE, SOUTH CAROLINA 29613

DIVISION OF SCIENCE AND MATHEMATICS

TO: All Secondary School Personnel Interested in the Western South Carolina Science Fair

FROM: Gilbert W. Fairbanks, Director of the Western South Carolina Science Fair

The Twenty-Fifth Annual Western South Carolina High School Science Fair will be held at Furman University, Greenville, South Carolina, March 29-30, 1979.

PARTICIPATING COUNTIES

The counties which comprise the Western South Carolina Region are: Abbeville, Anderson, Greenville, Greenwood, Laurens, Oconee and Pickens. A student may participate in only one regional or state fair which sends winners to the International Science Fair.

Exhibits and project in the areas of sciences and mathematics are invited. Entrants will be judged in two divisions. Students in Junior High or Middle Schools will be in the Junior Division; those in Senior High Schools will make up the Senior Division. Ninth grade students may enter either Division at the discretion of the sponsoring teacher.

Only individual entrants in the senior division are eligible to compete for the top prize of an all-expense-paid trip to San Antonio, Texas, to compete in the Thirtieth International Science and Engineering Fair.

CLASSIFICATION OF EXHIBITS

Exhibits may be entered in the areas of Biology, Chemistry, Geology, Mathematics, Physics and Psychology. No group exhibits are being accepted this year. Exhibits may be reclassified at the discretion of the Science Fair Committee.

GENERAL RULES

Exhibits are limited to 30 inches front to back and four feet side to side. Electric current (110 AC) will be available on request. Neither running water or gas will be furnished. All the work on the exhibits must be done by the exhibitors and must be so certified on the application by a teacher.

Dangerous chemicals, open flames, explosives, disease causing organisms and poisonous reptiles are forbidden. Exhibits may be refused for reasons of safety, sanitation or the best interest of the Fair. Exhibits must be brought to the Fair, cared for, and removed from the Fair by the exhibitor. The Science Fair Committee and cooperating groups will assume no responsibility for loss or damage to any exhibit.

Exhibits must be put in place between 1:00 and 4:00 p.m. on Thursday, March 29 and must be removed between 4:00 p.m. and 9:00 p.m. on March 30. Judging will take place on the afternoon of March 29 and morning of March 30.

PRESENTATION OF AWARDS

An awards banquet will be held in the Dining Hall at Furman University at 7:30 p.m. on Friday, March 30. The cost will be $2.50 for adults and $1.75 for participants. Awards will be given in each area in addition to overall winners and numerous special awards.

RULES FOR PROJECTS WITH LIVE ANIMALS

Although experiments involving live animals may be done in accordance with regulations and with proper certification, NO LIVE and/or PRESERVED ANIMALS MAY BE DISPLAYED AT THE SCIENCE FAIR. PHOTOGRAPHS of surgical technique, dissections, autopsies and/or other lab techniques depicting vertebrate animals in other than normal conditions, MAY NOT BE DISPLAYED, but may be contained in a notebook accompanying the exhibit. Students planning to use animals must begin the certification process prior to acquiring the animal. Certification forms, as well as rules and regulations, may be obtained by writing to or calling the Science Fair Director.

STANDARDS FOR JUDGING

Creative Ability

-30%

Does the project show creative ability and originality in the question asked, the approach to the problem, the analysis and interpretation of the data, and the construction and use of equipment?

Scientific Thought

-30%

Is the problem stated clearly; is it capable of solution, are the variables recognized, are the conclusions definite and supported by data, are there literature citations?

Thoroughness

-15%

Does the project carry out its purposes to completion, within scope of original aims if not appropriate, are they complete?

Skill

-15%

Does the student have the skills required to do all the work necessary or did he depend on others for much of the work done?

Clarity

-10%

Is the student able to explain the project in a clear and concise manner, and how does the project display explain itself?

VISITS BY CLASS GROUPS

Groups of students accompanied by a teacher are welcome to visit the Fair if the visit will serve a useful purpose in the education of the students. Arrangements for group visits should be made by contacting the Director. Soft drinks and snacks will be available in the science building.

ENTRY REQUIREMENTS

Entry forms and forms for advanced certification of experiments involving live vertebrate animals or embryos may be obtained by writing to the Director of the Fair. Because of space limitations the number of exhibits may have to be limited. Schools are urged to send only the most promising exhibits selected at the school science fair. Each entry blank will require a brief abstract of the project to be exhibited. In the event that the number of exhibits must be limited, the Science Fair Committee will select those entries that appear to be most deserving. The deadline for receipt of entry blanks is March 27.

Further information can be obtained from the Director of the Fair. Suggestions are also welcomed. We want to make the Fair as rewarding as possible for the participants.

Dr. Gilbert W. Fairbanks
Director of Science Fair
Furman University
Greenville, South Carolina 29613
Telephone 294-2084/294-2085

APPENDIX F

APPENDIX G

AIDS FOR YOUR FAIR

37th International Science and Engineering Fair Announcement Flyer

This announcement flyer describes the science and engineering fair program and the activities being planned for Finalists at the 37th International Science and Engineering Fair to be held in the Tarrant County Convention Center, Fort Worth, Texas. It can be effectively used by science and mathematics teachers to stimulate student project investigations. As a promotion piece, the announcement can inform prospective sponsors or financial supporters of your fair and can be used for your publicity program.

The announcement is a self-mailer which provides space for your message and imprint, or for your return address stamp. Copies are available free plus postage and handling charges of 3¢ each.

ABSTRACTS International Science and Engineering Fair — Three editions

The finalists whose project abstracts are reported in these books won the honor of presenting their projects at the 34th ISEF in Albuquerque, New Mexico in May 1983; the 35th ISEF in Columbus, Ohio in May 1984; and the 36th ISEF in Shreveport/Bossier City, Louisiana in May 1985. These books are useful for students seeking ideas for project investigations and should be a must in every school library. 1983 edition $1.50, 1984 edition $3.50, and 1985 edition $5.00. Set of three editions, $8.00.

International Science and Engineering Fair Research of the Finalists

Copies of the ISEF Research of the Finalists of previous years contain titles of projects entered, plus the name, affiliated fair, high school, home town and teacher of each of the Finalists.

The catalog is very useful to teachers in suggesting topics for a project investigation. It can also serve as an effective promotion piece to show prospective fair supporters the variety and sophistication of high school students' interests and work in science and engineering. Copies are available free plus postage and handling charges of 10¢ each.

37th International Science and Engineering Fair Judging Guide

The ISEF Judging Guide provides detailed information on the important aspects and guidelines which are involved in the vital function of judging. Though the Guide is designed for use by the ISEF judges, the information is adaptable and equally useful to affiliated fair judges. It contains sections on General Information, Judging Criteria and Judging Procedure. Copies are available in any quantity at 50¢ each.

Rules of the 37th International Science and Engineering Fair

The 28-page Rules booklet contains the ISEF rules for display size, quarantine, safety, animal research, human subjects, recombinant DNA, and tissues, and includes the necessary Certification, Research Plan and Bibliography forms which must be completed. Copies are available at 50¢ each.

REPRINTED WITH PERMISSION OF - Science Sevice, Inc.; Washington, D.C.

ISEF PROJECT CATEGORIES

Note: This preliminary list of Category Descriptions has been made up in response to the many requests for clarification in order to help students and teachers make category selections. We invite your comments.

Category Descriptions:

ISEF Grand Awards in thirteen different categories are sponsored by the General Motors Foundation. The categories and examples of the types of projects belonging to each are as follows:

Behavioral and Social Sciences: Psychology, sociology, anthropology, archaeology, ethology, ethnology, linguistics, animal behavior (learned or instinctive), learning, perception, urban problems, reading problems, public opinion surveys, and educational testing, etc.

Biochemistry: Molecular biology, molecular genetics, enzymes, photosynthesis, blood chemistry, protein chemistry, food chemistry, hormones, etc.

Botany: Agriculture, agronomy, horticulture, forestry, plant biorhythms, palynology, plant anatomy, plant taxonomy, plant physiology, plant pathology, plant genetics, hydroponics, algology, mycology, etc.

Chemistry: Physical chemistry, organic chemistry (other than biochemistry), inorganic chemistry, materials, plastics, fuels, pesticides, metallurgy, soil chemistry, etc.

Computer Science: New developments in software or hardware, information systems, computer systems organization, computer methodologies, and data (including structures, encryption, coding and information theory), etc.

Earth and Space Sciences: Geology, geophysics, physical oceanography, meteorology, atmospheric physics, seismology, petroleum, geography, speleology, mineralogy, topography, optical astronomy, radio astronomy, astrophysics, etc.

Engineering: Civil, mechanical, aeronautical, chemical, electrical, photographic, sound, automotive, marine, heating and refrigerating, transportation, environmental engineering, etc. Power transmission and generation, electronics, communications, architecture, bioengineering, lasers, etc.

Environmental Sciences: Pollution (air, water, land), pollution sources and their control, waste disposal, impact studies, environmental alteration (heat, light, irrigation, erosion, etc.), ecology.

Mathematics: Calculus, geometry, abstract algebra, number theory, statistics, complex analysis, probability, topology, logic, operations research, and other topics in pure and applied mathematics.

Medicine and Health: Medicine, dentistry, pharmacology, veterinary medicine, pathology, ophthalmology, nutrition, sanitation, pediatrics, dermatology, allergies, speech and hearing, optometry, etc.

Microbiology: Bacteriology, virology, protozoology, fungal and bacterial genetics, yeast, etc.

Physics: Solid state, optics, acoustics, particle, nuclear, atomic, plasma, superconductivity, fluid and gas dynamics, thermodynamics, semiconductors, magnetism, quantum mechanics, biophysics, etc.

Zoology: Animal genetics, ornithology, ichthyology, herpetology, entomology, animal ecology, anatomy, paleontology, cellular physiology, animal biorhythms, animal husbandry, cytology, histology, animal physiology, neurophysiology, invertebrate biology, etc.

Category Interpretations:

It is impossible to develop category descriptions which can be applied to any and all projects without some questions. In particular, the increasingly interdisciplinary nature of science and engineering means that many projects will draw upon more than one field. To determine a project category, it may therefore be necessary to identify the primary emphasis.

For example, limnology is defined as the scientific study of the physical, chemical, meteorological, and biological conditions in fresh water. A project in limnology would thus have to be considered from the point of view of its primary emphasis (physics, chemistry, etc.) to be placed in the appropriate category.

Below is a list of project areas about which questions frequently arise. This is not a complete list, and is simply given to provide some basis for interpretation of the category descriptions.

Instruments:

The design and construction of a telescope, bubble chamber, laser, or other instrument would be Engineering if the design and construction were the primary purpose of the project. If a telescope were constructed, data gathered using the telescope, and an analysis presented, the project would be placed in Earth and Space Sciences.

Marine Biology:

Behavioral and Social Sciences (schooling of fish), Botany (marine algae), Zoology (sea urchins), or Environmental Sciences (plant and animal life of sea, river, pond).

Fossils:

Botany (prehistoric plants), Chemistry (chemical composition of fossil shells), Earth and Space Sciences (geological ages), and Zoology (prehistoric animals).

Rockets:

Chemistry (rocket fuels), Earth and Space Sciences (use of a rocket as a vehicle for meteorological instruments), Engineering (design of a rocket), or Physics (computing rocket trajectories). A project on the effects of rocket acceleration on mice would go in Medicine and Health.

REPRINTED WITH PERMISSION OF - Science Sevice, Inc.; Washington, D.C.

APPENDIX H

APPENDIX I

JUDGING CRITERIA FOR 1984

The International Science Fair is judged on the basis of five criteria. These criteria and the respective maximum scores are:

I.	Creative Ability	(30%)
II.	Scientific Thought	(30%)
III.	Thoroughness	(15%)
IV.	Skill	(15%)
V.	Clarity	(10%)

Post regional fairs have also been judged on this basis. For 1983, the five criteria are each broken down into two or three categories. The criteria and categories are:

I. Creative Ability (30%)

A. Use of Materials and Equipment Available (10%) -- The score in this category reflects how well the student has used his own imagination and the resources available to him to complete the project. A project made from cardboard and duct tape (total cost under $5) could receive a much higher score than a computer built from an expensive kit.

B. The Display (10%) -- A major part of a science fair project is communication. The display should catch the attention and briefly explain what the project is about. The score in this category reflects how clearly and creatively the display communicates the answer to two questions about the project. They are:
1. What hypothesis or area of science does the project deal with?
2. What were the results of the project? What did the data indicate? What conclusions could be drawn?

C. The Write-Up (10%) -- The write up should be a formal, written narrative describing the following:
1. Statement of the problem.
2. The details of the design of the equipment. Drawings or plans used in the construction should be included.
3. The exact procedure followed (all records and databooks should be included).
4. A summary of all data. This should include graphs, tables, etc.
5. The conclusions supported by the investigation.

The score in this category reflects how well the investigation enlightens the problem.

II. Scientific Thought (30%)

A. The Student's Presentation to the Judge (20%) -- A major purpose of the science fair is to encourage original scientific thought. The score in this category reflects the extent the student is able to explain his project to the judge. This explanation should reflect the student's own understanding and should not be a memorized speech drawn from books and teachers.

B. The Write-Up (10%) -- The write up is judged on the extent to which it shows original scientific thought. Ideas and principles drawn from outside resources should be combined and used by the student in an original format. Material simply copied from texts will be rated low.

III. Thoroughness (15%)

A. Research and Data Collection (5%) -- A high score is given in this category for a project which is well planned and takes account of all variables affecting the experiment. Key measurements should be repeated.

B. Analysis of the Data (5%) -- The score in this category reflects how well the student used the data he has collected. Graphs and error analysis are expected where relevant.

C. Write-Up and Display (5%) -- The project should be well documented and represent a complete study. While a good project may end up suggesting further research in several areas, it should provide some sense of progress in the specific area defined for it.

IV. Skill (15%)

A. Observational and Design Skills (8%) -- The score in this category is based on the extent to which the project reflects skillful efforts on the part of the student in the process of data collection. Skill could be manifested in the design and/or construction of the equipment needed for the investigation. In instances were existing equipment is used, credit will be given for the design of the experimental program; i.e., the ways in which existing equipment or facilities are used.

B. Analytical and Computational Skills (7%) -- The score in this category reflects a judgement of the skills demonstrated in the analysis of the data. Computations and error analysis should be accurate and should represent work done by the student. Calculations done mechanically (by computer or programmable calculator) will be graded lower than hand calculations UNLESS the student writes the program used by the machine.

In summation, the skill demonstrated by the student is being judged. Sophisticated equipment or computation techniques do not necessarily improve the project's score.

V. Clarity (10%)

A. Presentation (5%) -- The score in this category reflects the extent that the student can succinctly express the following things to the judge:
1. The problem he is dealing with.
2. The nature of his investigation.
3. The conclusions suggested by his investigation

B. The Write-Up (5%) -- The write-up is judged in much the same manner as the presentation. Extra attention will be given to figures, the labeling of graphs, tables, etc. A high score is given for a write-up which is entirely self-explanatory.

AMERICAN CHEMICAL SOCIETY - First Award $250; Second Award $150; Third Award $100; Fourth Award $75. Each winner will receive an award plaque plus a subscription to Chem Matters. Six Honorable Mention Awards consisting of a certificate plus a subscription. In addition, the sponsoring teachers and schools of all winners will receive certificates.

AMERICAN COMMITTEE FOR THE WEIZMANN INSTITUTE OF SCIENCE - First Award, an all-expense-paid trip and a scholarship to the 18th International Summer Science Institute at the Weizmann Institute of Science in Rehovot, Israel, summer, 1986.

AMERICAN INDIAN SCIENCE AND ENGINEERING SOCIETY - Two awards of $100* for projects that best represent the relationship between science/engineering and American Indian culture.

AMERICAN INTELLECTUAL PROPERTY LAW ASSOCIATION - First Award $250; Second Award $125; Third Award $100; Three Honorable Mention Awards of $50 each.

AMERICAN MEDICAL ASSOCIATION - Citation plaques and $250 for up to ten students with outstanding exhibits in medical sciences or health.

AMERICAN METEOROLOGICAL SOCIETY - First Award of $250 and Second Award of $100 for the best exhibits in the area of atmospheric and related oceanic and hydrologic sciences. An Honorable Mention will receive a certificate and an AMS book.

AMERICAN OPTOMETRIC ASSOCIATION AND THE AUXILIARY TO THE AMERICAN OPTOMETRIC ASSOCIATION - First Award $250; Second Award $50; Third Award $25. A one-year subscription to the Journal of the American Optometric Association, and a plaque to each. Fourth, Fifth and Sixth Awards, Certificates of Honorable Mention.

AMERICAN PHYTOPATHOLOGICAL SOCIETY - First Award $250; Second Award $150; Third Award $100; Fourth Award $50. Certificates to all winners.

AMERICAN PSYCHOLOGICAL ASSOCIATION - First Award $250 and plaque; Second Award $150; Third Award $100. Six Honorable Mentions will be named.

AMERICAN SOCIETY FOR MICROBIOLOGY - First Award of a plaque, a Certificate of Merit and $250. The high school also receives a plaque and the sponsor receives a certificate; Second Award of a plaque, a Certificate of Merit and $75. The high school also receives a plaque and the sponsor receives a certificate. A plaque, a Certificate of Merit, and $25 are given to each of three Honorable Mention winners. Each of the three sponsors receives a certificate.

AMERICAN SOCIETY OF AGRONOMY - First Awards of $100 and certificates given in three categories: Crops, Soil, and Environment. School libraries of all three winners receive subscriptions to Journal of Environmental Quality and Crops and Soils.

AMERICAN SOCIETY OF CIVIL ENGINEERS - First Award $100;* Second Award $75;* Third Award $50.*

AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION - First Award $250, plaque and a subscription to the Journal of Speech and Hearing Research and a copy of The Speech Chain. Honorable Mention awards to two students including complimentary subscriptions to the above mentioned publications.

(*Amounts under revision.)

AWARDS AT THE ISEF

About 700 ISEF Judges and Special Awards Judges will select winners of more than 500 awards which will be presented at the ISEF. This will require one full day of judging and three different award presentation programs. The most valuable award, of course, is the opportunity for the Finalist to participate in the ISEF.

Science Service presents the following recognitions:

- Each Finalist receives a rainbow-ribboned silver medal with an embossed gold science emblem.
- A special certificate bearing a colored facsimile of the ISEF medal and giving the project title, name of Finalist, school and sponsoring organization is presented to each Finalist.
- Similar certificates of commendation are sent to the Finalist's sponsoring teacher and school.

GENERAL MOTORS ISEF GRAND AWARDS

Awards of First Place ($250), Second Place ($175), Third Place ($100), and Fourth Place ($50) are sponsored by General Motors in each of thirteen categories. In addition, two finalists are chosen to attend the Nobel Prize Ceremonies in Stockholm. Schools of the First Award Winners receive plaques and a $250 equipment/book purchase grant. Winners are selected by more than 400 eminent scientists and engineers who serve as ISEF Judges.

SPECIAL AWARD DONORS

Special Awards are given by many different scientific, engineering, industrial and Federal organizations which participate in the ISEF. Each sends its own panel of judges for the selection of winners in specialized fields. The following is a preliminary list of the Special Award donors and their awards:

ACOUSTICAL SOCIETY OF AMERICA - First Award $100, Second Award $75. One to three Honorable Mentions will be awarded. One-year student membership in ASA to each winner.

ALLEGHENY INTERNATIONAL, INC. - Five cash awards of $250 and certificates in recognition of projects demonstrating a successful research application of use to society. Five book/equipment awards of $250 and plaques to winners' schools.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS - First Award $250, Second Award $200; Third Award $150. A Fourth Award of $150 and a Fifth Award of $100 will be presented by local organizations.

AMERICAN ASSOCIATION OF PHYSICS TEACHERS - First Award $250; Second Award $200; Third Award $150. One-year membership in AAPT and AAPT publications to each winner.

AMERICAN ASTRONAUTICAL SOCIETY - First Award of an expenses-paid trip to an AAS national meeting or to an aerospace laboratory and a certificate; Second and Third Awards of a certificate. All winners receive a one-year subscription to the AAS Newsletter, a one-year student membership, a copy of the latest issue of the AAS Journal, and the latest book from the AAS Science and Technology Series.

AMERICAN VETERINARY MEDICAL ASSOCIATION - Ten First Awards each consisting of $100* and a plaque, for outstanding project or projects in animal health, public health, comparative medicine, biomedical research and/or food animal health.

ASSOCIATION FOR COMPUTING MACHINERY - First Award $250 and a subscription to Communications of the ACM and Computing Surveys. Two Honorable Mentions consisting of a year's subscription to the above mentioned publications.

ASSOCIATION FOR WOMEN GEOSCIENTISTS FOUNDATION - First Award of $100, a plaque, and a one-year subscription to GAEA to a Finalist in the Earth and Space Category. Two Honorable Mentions.

BALL ELECTRONIC SYSTEMS DIVISION AND BALL AEROSPACE SYSTEMS DIVISION - First Award expense-paid trip to the Ball Research and Development laboratories in Boulder, Colorado, and certificate. Second Award $250 cash and certificate. Third Award $100 cash and certificate. Winners' sponsor-teachers receive certificates.

BAUSCH & LOMB ASTRONOMICAL TELESCOPE DIVISION - First Award of a Bausch & Lomb "4000" telescope to the winner and a matching award to the winner's school.

BDM CORPORATION - First Award complete IBM Computer System; Second Award Hewlett Packard Computer.

BUREAU OF RECLAMATION/U.S. DEPARTMENT OF THE INTERIOR - A Certificate of Achievement, summer employment with the Bureau of Reclamation, a letter from the Commissioner, and a customized paperweight for best exhibit related to water resources development (hydroelectric power generation and transmission, dam design and construction, water conservation, irrigation management, etc.). In addition, the Reclamation Technical Club in Denver will award $150 to the First Place Award Winner. Certificate of Achievement, a letter from the Commissioner and a customized paperweight to Second and Third Place Winners in water resources development and management. In addition, the Reclamation Technical Club will award checks of $100 and $50 each, respectively, to the Second and Third Place Award Winners. Certificates of Achievement, letters from the Commissioner, and customized paperweights to two Honorable Mentions.

EASTMAN KODAK COMPANY - Up to ten $250 awards and certificates for best use of photography in displaying or developing a project. Up to ten $50 Honorable Mention awards and certificates will also be presented. Teachers of winners and Honorable Mentions will receive certificates. The student winners and their teachers will receive one-year subscriptions to Science News, a Science Service publication.

ENTOMOLOGICAL SOCIETY OF AMERICA - First Award $175; Second Award $100; Third Award $75.

GENERAL MOTORS CORPORATION - Up to ten awards of $250, certificates and special awards to winners for scientific studies of import to the field of transportation.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC. - First Award $100; Second Award $75; and Third Award $50. Certificate to each winner.

IEEE COMPUTER SOCIETY - First Award $250, Second Award $100, and Third Award $75.

(*Amounts under revision.)

INTERNATIONAL AEROSPACE HALL OF FAME - First Award $250, lifetime membership in the Hall of Fame, historic artifacts, subscriptions to Aviation Week and Space Technology, expenses paid trip to San Diego for the annual investiture ceremony.

JUNIOR ENGINEERING TECHNICAL SOCIETY - First Award $100; Second Award $75; Third Award $50. Students, teachers and schools will receive engraved plaques.

MARINE TECHNOLOGY SOCIETY/U.S. NAVAL INSTITUTE - Awards given in two categories: Oceanographic Science and Ocean Engineering. First Awards $250; Second Awards $50, Third Awards $25. In addition, all award winners will be given one-year student memberships in both the Marine Technology Society and the U.S. Naval Institute. Books printed by the Naval Institute awarded to the winners as well as to their schools.

MATHEMATICAL ASSOCIATION OF AMERICA - First Award $75 plus a set of the New Mathematical Library (NML); Second Award $50 plus the NML; Third Award $25 plus the NML.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION - Certificates of Merit and an expense-paid trip to a NASA Center to each of eight selected finalists and their teachers. Up to 12 Honorable Mention Awards at the discretion of the Judges.

THE OHIO STATE UNIVERSITY - Four $8,000 scholarships plus waiver of out-of-state fees (when appropriate), payable $2,000 per year; and eight Alternates will be named to the scholarships. Three $500 partial scholarships for the mathematically talented to the Arnold Ross Summer Program.

OPTICAL SOCIETY OF AMERICA - First Award $250; Second Award $100; and up to three Honorable Mentions for exhibits in optical sciences. All winners will receive one-year Student Memberships in OSA.

PATENT AND TRADEMARK OFFICE/U.S. DEPARTMENT OF COMMERCE/PATENT OFFICE SOCIETY - Grand Award of $250 and American Flag which has flown over the Nation's Capitol; six First Place Awards of $100; seven Citations of Merit of $50 in each of the following categories: Mechanical Engineering; Electrical Engineering; Design and Visual Impact; the combined fields of Chemistry and Botany; the combined fields of Medicine and Health and Zoology; the combined fields of Biochemistry and Microbiology; and the combined fields of Mathematics and Computers and Earth and Space Sciences.

SIGMA XI, THE SCIENTIFIC RESEARCH SOCIETY - Three First Awards, each consisting of $200; three Second Awards, each consisting of $100; for those projects that best exemplify the interdisciplinary aspects of science. In addition, each winner will receive a certificate of recognition and a year's subscription to American Scientist; student's school will receive a year's subscription to American Scientist for the school library.

SOCIETY OF EXPLORATION GEOPHYSICISTS - First Award an expense-paid visit to a city with major geophysical facilities for the winner and his or her science instructor; Distinguished Achievement Award Certificate; engraved plaque presented to the school of the winner; subscription to the Society's two publications, Geophysics and The Leading Edge for as long as the student stays in the earth science educational area. Two Alternate Awards of Certificates and subscriptions to the Society's two monthly publications as above. Instructors will receive Certificates of Commendation.

SOCIETY OF MANUFACTURING ENGINEERS - First Award $250; Second Award $100; Third Award $50; for projects in the area of engineering applications in processing industries.

APPENDIX K - BIBLIOGRAPHY

B O O K S

Langley, R. (1970). Practical Statistics Simply Explained . New York: Dover

Croxton, F. E. (1953). Elementary Statistics . New York: Dover

Freund, J. E. (1960). Modern Elementary Statistics . New Jersey: Prentice-Hall, Inc.

Ary, D. & Jacobs, L. & Razavieh, A. (1979). Introduction To Research In Education . New York: Holt, Rinehart and Winston

Norman, R. W. (1973). Experimental Biology . New Jersey: Prentice-Hall, Inc.

Washington, A. J. (1970). Basic Technical Mathematics With Calculus . California: Cummings Publishing Company

Quick, J. (1978). A Short Book On The Subject Of Speaking . New York: McGraw-Hill

Cotton, F. A. & Lynch, L. D. (1968). Chemistry An Investigative Approach . Boston: Houghton Mifflin Company

American Psychological Association. (1983). Publication Manual Of The American Psychological Association . (3rd Ed.). Washington, D.C. : American Psychological Association

Youden, W. J. (1985). Experimentation & Measurement . (2nd Ed.). Washington, D. C.: National Science Teachers Association

B O O K L E T S

Lyon, L. A. (1980). Guidelines For High School Students On Conducting Research In The Sciences . North Carolina: Moore Publishing Company

Robnett, B. (1975). The South Carolina Junior Academy Of Science Handbook . Columbia: The South Carolina Academy Of Science.

Garland, J. & Gustafson, D. (1985). Science Fair Handbook . California: The Fresno Bee

Science Fair News - Expand Your Universe . (1985). Chicago, Ill: Museum of Science and Industry.

ARTICLES

Rowson, D. J. (1985). Competing. The Science Teacher , Dec., 38-44

House, K. (1986). Wooly worms, and Natural Selection. The American Biology Teacher , 48 , 242-244

SCIENCE PROJECTS — A MODULAR APPROACH

Dear Science Teacher:

Competitive fairs have been a part of high school science programs for several years. Though designed to encourage innovative research and recognize superior achievement, these fairs often fall short of their goal. Poor planning, a shortage of time, a lack of incentive on the part of the student and a lack of direction on the part of the teacher result in fairs which are not truly competitive and are little more than displays of time-worn topics.

In an attempt to correct this problem and to give both teacher and student definite guidelines to follow in producing successful science fairs projects, I have developed a step-by-step manual for my high school science department. "SCIENCE PROJECTS — A MODULAR APPROACH" (SEE ATTACHED) suggests methods for selecting original topics, lists sources of information, outlines procedures for experimentation, describes exhibition techniques, and provides checklists and worksheets for the teacher to help the student insure well-planned and coordinated projects.

As any teacher who has required science projects knows, the time involved in directing a single student from the formulation of a research topic to published results is often tremendous. Multiply this time by the usual 130 student load, add the regular classroom preparation time, and a measure of the total hours required to incorporate science fair projects in a curriculum may be understood. The modular approach helps this time problem in three specific ways:

(1) It allows a teacher to quickly monitor each student's project, especially through the use of the manual's check list.

(2) It provides flexibility in scheduling; the manual may be used for a short "mini-course" in the scientific method or may be extended over a long period of time.

(3) The module permits long-range planning and prevents last-minute scrambles. Teachers can plan schedules for the assignments, pass out the booklets, make periodic checks on student progress, and efficiently evaluate completed projects.

With the aid of the science fair module described above, Riverside High School students have won more awards in the past six Western South Carolina Science Fairs than students from any other participating school, received a disproportionate number of grants from the South Carolina Junior Academy of Science and the Clemson University Chapter of Sigma-Xi, sent two students to the international science fair in May of 1986, and had two Westinghouse honors group winners.

Given this success, I would like to share SCIENCE PROJECTS — A MODULAR APPROACH with all of the high school and middle schools throughout the county.

There is still time to order and receive the modules to prepare for this year's competitions. Order 20 or more today and receive a $2.50 per book discount.

Thanks — Mike Farmer, Teacher
Riverside High School

APPLIED EDUCATIONAL TECHNOLOGY
P.O. Box 193
Tigerville, S.C. 29688

Name _____

Organization _____

Mailing Address _____

City _____ State _____

Zip _____ Phone _____

Purchase Order # _____

Please ship _____ copies of "Science Projects - A Modular Approach" as follows:

_____ Individual copies @ $7.50 each ..... _____

_____ Copies @ $5.00 each in 20 copy quantities ..... _____

_____ Postage @ $.50/copy ..... _____

Total _____

Shipping Label - Please complete the below label with the address to which you would like your order shipped:

SHIP TO _____

_____

_____

_____